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JOURNAL OF THE
SOCIETY OF GLASS TECHNOLOGY

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JOURNAL

OF THE

SOCIETY OF GLASS TECHNOLOGY

COMPRISING

PROCEEDINGS AND REPORTS, TRANSACTIONS

AND

ABSTRACTS OF PAPERS FROM OTHER JOURNALS

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1920. Vol. IV.

Published by the Society of Glass Technology.
Secretary Dr. W. E. S. Turner, The University, Sheffield.

PRINTED IN GREAT BRITAIN BY
THE CORNWALL PRESS, LTD., PARIS GARDEN,
STAMFORD STREET, LONDON, S.E. 1.

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The Society of Glass Technology.

THE SOCIETY OF GLASS TECHNOLOGY was inaugurated at a meeting in the University of Sheffield, on Thursday, November 9th, 1916.

Its object was defined as the general advancement of the various branches of Glass Technology by the association of persons interested in glass and glassware; the reading and discussion of papers; the publication of scientific information on glass technology; the formation of a library and museum.

All persons or associations of persons interested in glass, whether from the point of view of the manufacturer, the distributor, the scientist, the user or collector, are eligible for membership.

Membership is of three classes: Collective Membership, open to Firms, Associations, and Committees; Ordinary Members, and Student Members, the annual subscription in each class being £3 3*s*., £1 10*s*., and 2*s*. 6*d*. respectively. Copies of the Constitution and Rules may be had on application to the Secretary, The University, Sheffield. The total number of members whose election has been confirmed is approximately 600.

Meetings of the Society are arranged monthly, except during the summer. One half of the meetings take place at Sheffield, the headquarters of the Society, the other meetings being held in different centres of the glass industry, as the Council decides. In this way local interest is stimulated.

The Society publishes a Quarterly Journal, containing the papers read to the Society and the discussions on the papers, together with abstracts of other papers of interest to members published in British and foreign journals. Each collective member may receive two copies and each ordinary member one copy.

Scientific communications on glass technology are invited for publication in the Journal.

A library of technical literature has been formed, and a list of the books available for reference or for loan may be obtained from the Secretary.

The Society of Glass Technology.

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VOL. III. (TRANS., 1919).

Page.	Line.	
126	Table 1	*for* " Fe_2O_4 " *read* " Fe_2O_3."
		for " As_2O_4 " *read* " As_2O_3."
273	10	*for* " white arsenious " *read* " arsenious oxide."

VOL. IV. (TRANS., 1920).

Page.	Line.	
10	10	*for* " 2·220 " *read* 2·20.
17	8	*for* " 2·220 " *read* " 2·20."
32	4*	*for* " 2,500,000 grams " *read* " 500,000 grams."
32	1*	*for* " 0·00086 " *read* " 0·0043 "
33	2	*for* " fifty times " *read* " ten times."

The address at the end (p. 136) of the paper by Mr. E. B. Christmas should be

PRUDENTIAL BUILDINGS, PINSTONE STREET, SHEFFIELD,

and not as stated.

Page.	Line.	
156	5*	*for* " 2·40 " *read* " 2·20."
219	14	*for* " 0·1013 " *read* " 0·1913."
220	21	*insert after* " Na_2CO_3," the symbols " $= Na_2SiO_3$ (glass)."

VOL. IV. (ABSTR., 1920).

Page.	Line.	
7	30	*for* " nitreous " *read* " vitreous."
48	under figure,	*for* " Fig. 12 " *read* " Fig. 21."
125	17	*for* " sulphate and magnesium " *read* " sulphate of magnesium."
137	1	*for* " urine " *read* " brine."
149	17	*for* " 433 " *read* " 435."

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* From bottom.

PROCEEDINGS

PROCEEDINGS

OF THE

SOCIETY OF GLASS TECHNOLOGY

PROCEEDINGS OF THE THIRTY-FIRST MEETING.

HELD in St. Thomas's Hall, Stourbridge, on Wednesday, January 21st, 1920, at 3 p.m., Mr. S. N. JENKINSON, President, in the Chair.

The election of Mr. W. M. Clark, of Cleveland, Ohio, as American Treasurer was carried unanimously.

The Secretary was authorised to send greetings, in the name of the Society, to the newly formed Glass Division of the American Ceramic Society.

Reference was made to the visit of the Society to America about the third week in August. It was requested that the names of those who wished to join the party should be sent in to the Secretary as soon as possible.

On the motion of the PRESIDENT, a cordial vote of thanks was given to the local manufacturers of Stourbridge who had so kindly granted permission to members to visit their works during the forenoon, as well as to the local manufacturers who had not only generously invited to luncheon members outside the Midland area, but had also engaged St. Thomas's Hall for the use of the meeting. In proposing the vote of thanks, special reference was made to Messrs. J. S. and H. S. Williams-Thomas for the great trouble they had taken in making arrangements for the Society's visit.

Mr. J. S. WILLIAMS-THOMAS, J.P., O.B.E., in replying to the vote of thanks, hoped that the Society's visit to Stourbridge would be periodic. By comparing notes and working together, they would be enabled to overcome their difficulties.

Dr. TURNER then gave a paper on "The Factory Inspection of Glassware."

Before giving the paper, Dr. Turner directed the attention of members to a very kind promise made to him by Mr. Arthur Kimes, Editor of the *National Glass Budget* in America, that he would willingly give any information in his power to members of the Society concerning the American glass industry. Dr. Turner also said that members who made a point of obtaining all the possible scientific information on glass might like to know that they would be welcomed as members of the Glass Division of the American Ceramic Society. He had forms of application, which he would be pleased to issue to any member.

In the discussion on the paper, there took part:—The President, Lt. E. A. B. Willmer, Dr. Travers, and Messrs. W. Proctor, J. Northwood, and R. H. H. Wood.

Lt.-Col. C. W. THOMAS followed with a paper entitled, "Note on a Glasshouse Pot of Special Construction," copies of which were distributed among those present. A specimen pot was exhibited. The paper elicited a lively discussion, to which contributions were made by the President, Dr. Travers, and Messrs. J. S. Williams-Thomas, R. H. H. Wood, J. Northwood, W. J. Gardner, and N. Bache, Lt.-Col. Thomas replying.

The last paper on the agenda was "The Relative Durabilities of Potash and Soda Glass for Artistic and Table Ware," by F. W. Hodkin, B.Sc., A.I.C., and W. E. S. Turner, D.Sc. A discussion followed, in which there took part the President and Messrs. E. A. Coad-Pryor, J. Northwood, and W. Butler.

The PRESIDENT intimated that contributions of papers from members would be welcomed..

During the morning, through the kindness of the respective directors, members had an opportunity of visiting the following works:—Messrs. King Brothers (Stourbridge), Ltd., Fireclay Works; Messrs. Stevens and Williams, Ltd., Brierley Hill Glass Works; Messrs. Thos. Webb and Corbett, Ltd., Coalbournhill Glass Works; Messrs. Thos. Webb and Sons, Ltd., Dennis Glass Works.

A social gathering of members of the Society took place at the Talbot Hotel, Stourbridge, at 1 p.m., when a luncheon was kindly provided by the local manufacturers.

The following members were elected:—

Collective Members.

Glasfabriek "Leerdam," Messrs.	Voorheen, Jeekel, Mijnssen and Co., Leerdam, Holland.

Ordinary Members.

Beaumont, Percy John	General Manager, Beaumont Glass Co., Morgantown, W.Va., U.S.A.
Bianchedi, Romulo	Consulting Engineer, Buenos Aires, Argentina.
Brenner, Ralph Ferguson, B.S.	Chief Chemist and Glassmaker, Bartlett-Collins Glass Co., Sapulpa, Oklahoma, U.S.A.
Buck, George Grofflin.	Glass Bottle Manufacturer, Baltimore, Md., U.S.A.
Christmas, Edwin Bossward	A.M.I.Mech.E., Consulting and Mechanical Engineer, Prudential Buildings, Sheffield.
Svanlund, A. H.	Director of Glass Works, Askersund, Sweden.
McLellan, Wallace Albert	c/o Messrs. Thos. Webb and Corbett, Ltd., Stourbridge.

PROCEEDINGS OF THE THIRTY-SECOND MEETING.

HELD in the Mappin Hall, Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, February 18th, 1920, at 3 p.m., Dr. M. W. TRAVERS, F.R.S., Vice-President, in the Chair.

The CHAIRMAN referred to the establishment of the Wood Prize. It was, he said, to commemorate the distinguished services rendered by Mr. Frank Wood, of Barnsley, in assisting in the founding of the Society, of which he was its first President.

Dr. Travers, on behalf of the Society, then handed to Sir W. H. Hadow, Vice-Chancellor of Sheffield University, a cheque for £105 8*s*. 6*d*., to be invested for the purpose of providing for the award of an annual "Wood Medal and Prize" in glass technology.

Sir HENRY HADOW, in accepting the gift, said he was led to believe that Sheffield University was the only one in the country that had a Glass Technology Department. It was a distinction to the city, and one of which the University was proud. The co-operation between academic bodies and large industrial bodies could only be of the greatest service to both. Each had something to learn from the other. The academic side of any scientific work, and especially of any applied science, needed to be tempered, corrected, and corroborated by practical experience from outside. He therefore cordially welcomed the co-operation between the Society and the University. The latter would do everything in its power to develop and encourage that co-operation. He hoped the foundation of the prize would set on the first steps of a career more than one member of the University who would do memorable service to the glass industry.

The CHAIRMAN then referred to the recent presentation in London to Dr. W. E. S. Turner, O.B.E., in appreciation of his services to the Society as Secretary and as Editor of the JOURNAL. He said there was a small balance remaining, and he had pleasure in handing Dr. Turner a cheque for the amount.

Dr. Turner referred to the trip to America which the Society was arranging for August and September, 1920. He said that already nearly twenty members had signified their intention of going, but he would be glad to have the names of any others who proposed to join the excursion. He reported that, without any request from him, a committee of welcome had been spontaneously set up in Pittsburgh to arrange for the comfort and entertainment of those who joined the excursion.

A vote of thanks was accorded to the University authorities for so kindly providing accommodation for the meeting. Sir W. H. Hadow replied.

The following paper was then read:—"The Preservation of Glass Furnace Refractories by Water Cooling," by E. B. Christmas, A.M.I.Mech.E. This paper was illustrated by numerous lantern-slides, and elicited a discussion, in which there took part the Chairman, Dr. Turner, and Mr. J. Connolly.

Mr. J. Connolly took the Chair while Dr. M. W. Travers gave his paper, entitled "A Glass Furnace embodying a New Principle of Gas Firing." Three coloured diagrams were exhibited. A discussion followed, in which there took part Messrs. W. P. Johnson and C. J. Peddle.

A kinematograph film was then exhibited by Messrs. Ingersoll-Rand Company, London, showing "The O'Neill Bottle Machine in Operation." The various processes shown in the film were explained by Mr. W. L. Van Meter. Great interest was shown in the exhibition, which attracted a discussion, in which Mr. F. O'Neill took part. Others who spoke were Dr. Turner, Mr. J. Connolly, and the Chairman.

The following members were elected:—

Collective Members.

Powell & Ricketts, Ltd., Messrs.	Phœnix Glass Bottle Works, Bristol.
Webb's Crystal Glass Co., Ltd., Messrs.	26, Hatton Garden, London, E.C. 1.

Ordinary Members.

Bartlett, Edward E.	Glass Manufacturer, 502, South Division Street, Sapulpa, Oklahoma, U.S.A.
Brown, Noel Alfred	Assistant Secretary, Messrs. Claudius Ash, Sons & Co., Ltd., Anglers' Lane, London, and "Overstrand," 80, North Road, Highgate, London, N. 6.
Burgess, M. L.	Secretary-Treasurer, Messrs. Marietta Manufacturing Co., Indianapolis, and 989, E. Drive, Woodruff Place Indianapolis, Ind., U.S.A.

Carder, George John	Principal, Art and Technical Institute, Wordsley, and Whinsfield, Brettell Lane, Stourbridge.
Grint, William Horace	Designer of Glassworks Plant, 2, Central Buildings, Westminster, London, and 11, Evershot Road Tollington Park, London, N. 4.
Handley, Bernard	Cut Glass Manufacturer, Sidney Street, Sheffield, and 308, Granville Road, Sheffield.
Söderhielm, Captain Ragnar	Glassworks Director, Drattninggatan 66, Stockholm, Sweden.
Walters, Arnold	Member Jun. Inst. Eng., Mechanical Engineer, Prudential Buildings, Sheffield, and "Rock Lea," Hathersage, via Sheffield.
De, Kunjabehari, B.A., B.Sc.	Engineer, The Allahabad Glass Works, Naini, United Provinces, India.
Hobbie, Edward Humphreys	Glass Manufacturer, The Mississippi Wire Glass Co., 220, 5th Avenue, New York, N.Y., U.S.A.
Mitchell, Percy José, M.I.Mech.E.	Consulting Engineer, 2, Central Buildings, Westminster, London, and 37, Avenue Road, London, N.W.
Vieweg, George Bowers	Assistant Manager, The Mississippi Glass Company, Morgantown, W.Va., U.S.A.
Winship, William W.	Manager, The Thermal Syndicate, Ltd., 5, East 41st Street, New York, U.S.A.

PROCEEDINGS OF THE THIRTY-THIRD MEETING.

HELD in the Societies Room, The Royal Technical College, Glasgow, on Wednesday, March 17th, 1920, at 2.30 p.m., the President, Mr. S. N. JENKINSON, in the Chair.

The SECRETARY announced the death of two members, Mr. G. A. Squires, of Sunderland, and Monsieur A. Wilzin, of St. Ouen, France. A vote of sympathy was thereupon passed unanimously.

Members were reminded of the Annual General Meeting on April 21st. Nominations for the offices of Vice-President and Member of Council were invited, to be received by the Secretary not later than March 31st.

The attention of members was also directed to the Annual Dinner, which would take place in Sheffield on the evening of the day on which the Annual Meeting would be held.

The PRESIDENT referred to the forthcoming visit to America, and intimated that the Secretary would be glad to have the names of those who proposed to join the excursion, so as to facilitate arrangements.

A cordial vote of thanks was accorded to Dr. H. F. Stockdale, F.R.S.E., Director of the Royal Technical College, for kindly providing accommodation for the meeting.

A hearty vote of thanks was also accorded to the firms who had so courteously granted permission to members to visit their works, namely, Messrs. Scottish Central Glass Works, Ltd., Alloa; Messrs. Kinghorn Bottle Co., Ltd., Kinghorn; Messrs. Edinburgh & Leith Flint Glass Co., Edinburgh. In acknowledging the vote of thanks, the PRESIDENT said they welcomed the Society to Scotland. It was the first time that the Society had held a meeting in Scotland, but he hoped it would not be the last.

Mr. W. L. VAN METER gave an account of "The O'Neill Bottle Machine," illustrated by a kinematograph exhibition of the machine in operation, arranged by Messrs. Ingersoll-Rand Company, of London. An interesting discussion followed, in which there took part the President, Messrs. G. Simpson, F. G. Clark, and Dr. Turner.

A paper was read by Mr. John Kaye, M.A., B.Sc., entitled, "The Evolution of a Costing System in a Glass Works."

The third paper on the agenda, "Some Faults in Common Glass Bottles," by Violet Dimbleby, B.Sc., and W. E. S. Turner, D.Sc., was read by the latter, and was illustrated by specimens of faulty bottles. It elicited a discussion, in which the following took part:—the President, Messrs. G. Simpson, J. H. Webster, G. P. Ogale, and A. S. Giles. Dr. Turner replied.

Owing to lack of time, a fourth paper was taken as read, namely, "The German Glass Industry during the War and after as revealed by its own Journals," by Dr. Turner.

The following members were elected:—

Collective Members.

Burdin & Co., Ltd., Messrs.	Manufacturers and Merchants of Glass Bottles, Station Glass Works, Knottingley, Yorks.
Liddle, Henzell & Co., Ltd., Messrs.	Ouseburn Glass Works, Newcastle-on-Tyne.
The Power Gas Corporation, Ltd., Messrs.	Producer Gas and Bye-Product Recovery Specialists, Parkfield Works, Stockton-on-Tees.
Baird, John, Ltd., Messrs.	Glass Manufacturers, Decorators and Merchants, 99, Milton Street, Glasgow.

Ordinary Members.

Bowen, George Malcolm	Fireclay Goods Manufacturer and Merchant, c/o Messrs. Bowen & Edwards, 93, Northwood Street, Birmingham.
Callie, John, B.A.	Business Manager & Director, Messrs. Richmond Glass Works, Ltd., Richmond, Surrey.
Cousen, Arnold, B.Sc., A.R.C.S., A.I.C.	Assistant Lecturer and Demonstrator, Department of Glass Technology, The University, Sheffield.
Hodgson, Reuben	Chairman of Directors, Ouseburn Glass Works, Newcastle-on-Tyne, and Wiseton Cottage, Brunton Park, Gosforth.
Illingworth, Charles Hunter	Middle Farm, Bramley, Hants.
Van Meter, William Lindon	c/o Messrs. Ingersoll-Rand Co., 165, Queen Victoria Street, London, E.C. 4
Boyden, Mrs. E. S.	Librarian, Messrs. American Optical Co., U.S.A., 2, Taft Street, Southbridge, Mass., U.S.A.
Willock, J., Junr.	Messrs. Glenpark Glass Bottle Co., 60, East Nelson Street, Glasgow.
Le Chatelier, Prof. Henry	Professeur à la Sorbonne, 75, Rue Notre Dame des Champs, Paris.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, BEING THE THIRD ANNUAL GENERAL MEETING.

Held in the Mappin Hall, Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, April 21st, 1920, at 2.30 p.m., the President, S. N. Jenkinson, Esq., in the Chair.

The Third Annual Report of the Council, together with the Balance Sheet, for the year 1919 having been circulated, was taken as read. Revision of the Balance Sheet having occurred subsequent to the circulation of the notice of the meeting, a new statement was presented showing a small balance on the right side. This balance did not include the cost value of the stock of Journals in the Society's possession, estimated at about £400.

The Report and Balance Sheet were approved. Their formal adoption was moved by Mr. W. F. J. Wood, and seconded by Mr. J. Connolly.

The Report and Balance Sheet were as follows:—

By the time a scientific society has produced its Third Annual Report it may be expected to have acquired a normal routine and to have settled down to a steady, if slow, growth. The normal routine, so far as meetings are concerned, may conceivably have been attained, but the growth of the Society, on the other hand, shows no sign of slowing down. The considerable list of applications for membership which is presented from meeting to meeting is an indication of the need of the Society; and the increasing interest in its work, both in this country and abroad, indicates an appreciation of the desire to be of service which is behind all the Society's efforts.

In the period under review, 144 members were elected as compared with 146 during 1918. The total consisted of 19 Collective, 121 Ordinary, and 4 Student Members. The total number of members on the roll on December 31st, 1919, was 516, comprised of 120 Collective, 392 Ordinary, and 4 Student Members. Amongst the applications for Ordinary Membership was a very large number from abroad, particularly from the United States, where the interest in the Society is very great. At the same time, applications from other countries are coming in, and at the end of the year there were resident abroad the following members:—

Australia	2	Japan	3
Canada	4	South Africa	2
China	1	Sweden	4
France	7	United States	70
India	6		

a total of 99, being nearly one-fifth of the total membership.

During the year the Society lost, by death, the following members:—

Sir Wm. Crookes, O.M., LL.D., F.R.S., Vice-President.
J. H. Crowther.
E. Hopkinson, M.Sc.

Nine members have also resigned, their names being as follows:—

A. M. Allan.
S. S. Allan.
T. G. Brown.
J. G. Campbell.
W. A. Norton.
A. W. Pearce.
J. W. T. Walsh, M.A., M.Sc.
A. C. Williams, Lt.-Col. R.A.
Miss M. Osborne.

The JOURNAL during 1919 has also grown considerably. Thirty-two papers were communicated to the Society, and of these 31 have already appeared in print. In addition, three addresses were delivered at the Annual General Meeting in April, but have not been printed. Volume III of the JOURNAL contains, in addition to the index, 57 pages of Proceedings and Reports, 32 papers, and the Presidential Address, comprising 285 pages of Transactions, and 362 Abstracts occupying 282 pages. It will be noted that there is an all-round increase over 1918, except that whilst the number of papers in the Transactions is greater, the actual number of pages occupied is slightly fewer. The most important increase is in the Abstracts, which this year have included Patent Specifications, both British and American, on a variety of subjects, particularly on furnaces and machinery for glass-making operations. The inclusion of these Abstracts largely accounts for the addition of nearly 100 pages to the Abstracts, and of more than 150 additional diagrams, which, although adding to the expense of production, increase the usefulness of the JOURNAL.

At the Annual General Meeting in April an effort was made by the Society to stimulate interest in the formation of a Research Association for the glass industry. The Council regards with satisfaction the successful formation of such an association, and it believes that the Society's work alone could have made such an association possible, since it brought into contact and friendly co-operation so many glass manufacturers of diverse interests who had hitherto remained unknown to one another. The Council trusts that that Association will be a source of strength to the industry.

The first Annual Dinner of the Society was held following the Annual Meeting in April, and proved a great success. The opportunity was taken of entertaining the retiring President, Mr. W. F. J. Wood, C.B.E., B.Sc., F.I.C., and to honour him for the work he had done on behalf of the Society.

A movement which was originated in February and approved by the Council, to raise a testimonial fund to commemorate the services of Mr. Wood as first President, and of Dr. Turner as Secretary, had its outcome at the December meeting of the Society, when presentations of silver were made both to Mr. Wood and to Dr. Turner. Further, in the case of Mr. Wood, the sum of £105 8*s*. 6*d*. was offered to and accepted by the University of Sheffield to found a "Wood Medal and Prize" in the Department of Glass Technology. In Dr. Turner's case, a cheque for nearly £220 was presented to him, the larger portion just before his visit to America. A balance-sheet for this fund is appended.

The Council gladly accepted the invitation of the American Ceramic Society to a joint conference in the summer of 1920 in America, and it looks forward with pleasant anticipation to the success of this visit and to the strengthening of ties between the two countries.

The Society's Library has grown considerably during the year, from approximately 100 volumes at the end of 1918 to 145 at the end of 1919. The Council has to acknowledge with thanks a donation of books from Mr. Harry Powell. It would also welcome similar gifts from other members of the Society.

During the year, the Refractories Research and Specifications Committee was strengthened by the inclusion of members of the refractories industry, and completed its Provisional Specification for Tank Blocks, Silica Bricks, and Clay for Pots.

A further extension of the Society's work consisted in the formation of a Glass Standards Committee, with at present three sub-committees to deal with the subjects of optical glass, glass for lampworking purposes, and bottles and general glass containers.

As predicted in the Report for 1918, the income of the Society has exceeded £1,000 during 1919. The Income and Expenditure Account and the Balance-sheet for the year are appended. It will be noted that the total income for 1919 amounted to £1,297 13*s*. 2*d*. The balance in hand at the beginning of the year was £45 7*s*. 5*d*.

As the result of the year's working, the balance has been increased to £53 11*s.* 7*d.* It will be noted that a very large proportion of the income was again absorbed in the production of the JOURNAL, the sum involved being very approximately £1050. The increase in cost is partly due to the big increase in the Abstracts section with its large number of diagrams, and partly due also to further increases in the printers' charges. The demand for the JOURNAL, however, is becoming very extensive, and the sales of back numbers are considerable, providing a steady source of income for the Society. The Council will shortly be called on to consider the question of reprinting Volumes I and II, so considerable is the demand for them.

Despite the increase in cost of publication, which absorbs most of the income of the Society, the financial position, the Council believes, is very satisfactory. At the Annual Meeting in April, 1919, it was decided that the subscription for Ordinary Members should be increased from 21*s.* to 30*s.* per annum. For the convenience of the American members of the Society, the Society decided that an American Treasurer should be appointed, and that the subscriptions of American members should be 15 dollars for Collective and 7 dollars for Ordinary Members. The additional income from subscriptions should make the financial position sounder, with a steady improvement from year to year, making it possible to undertake other lines of service for the benefit of its members.

One scheme which has been before the Society, and received hearty approval, is the publication of a series of Works of Reference. At the present time the financing of this proposed venture is still under consideration, and will, the Council hopes, shortly be satisfactorily settled.

SOCIETY OF GLASS TECHNOLOGY

1919 Dinner Fund Account.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
To Sundry Donations	40	17	6	By Grand Hotel	32	10	3
,, Balance	2	16	9	,, Printing	4	9	0
				,, Entertainer	2	2	0
				,, Postages	1	3	10
				,, Gratuities	1	10	0
				,, Cheques	0	0	8
				,, Printing	1	18	6
	£43	14	3		£43	14	3

February 14*th*, 1920.

Examined and found correct,

G. Wilson Clarke.
Frederick Lax.

SOCIETY OF GLASS TECHNOLOGY.

Dr. Turner and Mr. Frank Wood Testimonial Fund.

Receipts.

	£	s.	d.
To Amounts subscribed	395	4	0
,, Bank Interest	1	8	0
	£396	12	0

Payments.

	£	s.	d.	£	s.	d.
By Cheque paid to Dr. Turner	185	0	0			
,, Cheque paid to Dr. Turner	34	7	6			
,, Dr. Turner's Tea and Coffee Service ...	42	18	0			
,, Postages, Printing, etc.	2	5	3			
				264	10	9
,, "Wood Prize," Sheffield University...	105	8	6			
,, Testimonial for Frank Wood, Esq. ...	24	7	6			
,, Stamps, Stationery, etc.	2	5	3			
				132	1	3
				£396	12	0

	£	s.	d.
Amount subscribed for Dr. Turner	£264	10	9
Amount subscribed for Mr. Frank Wood	132	1	3
	£396	12	0

Examined and found correct,

G. Wilson Clarke.
Frederick Lax.

March 30*th*, 1920.

SOCIETY OF GLASS TECHNOLOGY.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED DECEMBER 31st, 1919.

EXPENDITURE.

	£	s.	d.	£	s.	d.
To Printing and distribution of Journal						
No. 9	191	12	11			
No. 10	239	5	5			
No. 11	208	4	5			
No. 12	271	14	4			
				910	17	1
,, Reprints of List of Members				27	9	0
,, Authors' Reprints				57	18	0
,, Printing Notices, &c., and Stationery				60	3	3
,, Abstractors' Remuneration				55	18	0
,, Expenses of Meetings				7	18	9
,, Travelling Expenses				6	16	9
,, Salaries (Assistant Secretary and Typist)				76	6	8
,, Advertising				5	0	0
,, Purchase of Books and Journals				12	2	7
,, Binding Books				8	1	2
,, Binding and Cases, Vol. III				24	9	6
,, Office Expenses (Petty Cash)				3	9	9
,, Postages, Telegrams, &c.				24	1	0
,, Cash Returned				2	4	0
,, Bank Charges				6	13	6
,, Excess of Income over Expenditure carried to Balance Sheet				8	4	2
				£1,297	13	2

INCOME.

	£	s.	d.
By Subscriptions:			
Collective, 120 at £3 3*s*. each	378	0	0
Ordinary, 360 at £1 1*s*. each	378	0	0
Student, 4 at 2*s*. 6*d*. each		10	0
,, Donations from American Members	1	6	8
,, Sale of Binding Cases	2	19	0
,, Journals Sold	261	10	6
,, Commission on Advertisements in 1919 Journals ...	257	0	0
,, Bank Interest	18	7	0
	£1,297	13	2

SOCIETY OF GLASS TECHNOLOGY.

Balance Sheet as at 31st December, 1919.

Liabilities	£	s.	d.	£	s.	d.	£	s.	d.
Amounts owing:—									
Printing and Distribution of									
Journal No. 11	208	4	5						
No. 12	271	14	4						
				479	18	9			
Reprints of List of Members				27	9	0			
Authors' Reprints				41	8	6			
Printing Notices, &c., and Stationery				19	4	3			
Binding and Cases, Vol. III				24	9	6			
Expenses of Meetings				4	4	9			
Salaries				34	13	4			
Advertising				1	5	0			
Subscriptions paid in advance.. ...				22	2	1			
Abstractors' Remuneration				55	18	0			
Travelling Expenses				2	0	0			
Postages				0	9	0			
							713	2	2
Balance from 1918 Balance Sheet ...				45	7	5			
Excess of Income over Expenditure for 1919				8	4	2			
							53	11	7
							£766	13	9

Assets.		£	s.	d.
Cash in Bank		509	13	9
Commission on Advertisements in 1919 Journals ...		257	0	0
Journals, etc., in Stock:—				
No. 1	5			
,, 2	125			
,, 3	108			
,, 4	94			
,, 7	13			
,, 8	27			
,, 9	103 and 200 Flat for Volumes			
,, 10	99 ,, 200 ,, ,, ,,			
Vol. I. Bound	104			
,, II. ,,	109			
Binding Cases. Vol. I.	127			
,, ,, ,, II.	57			
		£766	13	9

We have examined the above Accounts with Pass Book, Vouchers, etc., and in our opinion they are correct, and exhibit a true view of the Society's affairs as at December 31st, 1919.

G. Wilson Clarke,
Frederick Lax.

March 30*th*, 1920

The election of officers for the year 1920–21 was then proceeded with. The following lists contain the names (1) of officers whose term of office expired, and (2) of members who were elected in accordance with the Rules of the Society:—

(1)	(2)
President.	
S. N. Jenkinson, M.B.E.	S. N. Jenkinson, M.B.E.
Vice-Presidents.	
Prof. J. W. Cobb, C.B.E., B.Sc., F.I.C.	Edward F. Chance, M.A., J.P.
S. W. Morrison, O.B.E.	Joseph Connolly.
H. P. Powell.	Prof. W. G. Fearnsides, M.A., F.G.S.
H. S. Williams-Thomas.	John Forster, O.B.E., J.P.
Ordinary Members of Council.	
Milton Asquith.	E. A. Coad-Pryor, B.A.
W. R. Barker.	J. H. Davidson, M.Sc., F.I.C.
R. S. Biram.	W. J. Gardner.
Prof. W. G. Fearnsides, M.A., F.G.S.	J. Kaye, M.A., B.Sc., F.I.C.
F. Swann.	Col. T. W. Simpson.
J. Connolly (*on election as Vice-President*).	F. B. Towers.
Treasurers.	
F. Sweeting (General).	F. Sweeting (General).
W. M. Clark, Ph.B. (American).	W. M. Clark, Ph.B. (American).
Secretary.	
W. E. S. Turner, O.B.E., D.Sc., M.Sc.	W. E. S. Turner, O.B.E., D.Sc., M.Sc.
Assistant Secretary.	
C. J. Peddle, M.Sc., F.I.C.	C. J. Peddle, M.Sc., F.I.C.
Auditors.	
G. Wilson Clarke.	G. Wilson Clarke.
Frederick Lax.	Fredefick Lax.

Mr. J. H. Davidson was elected to fill the vacancy caused by the election of Mr. Connolly as Vice-President, and will retire therefore in 1921. The newly-elected Vice-Presidents and Ordinary Members of Council are due to retire in 1923.

The President, in the course of a short address, spoke of the increasing membership of the Society, more than 50 new members having been elected since the beginning of 1920. The policy of the Society, he said, was that of co-operation and getting people to work together. He asked the members to continue doing what they had done in the past, to co-operate to the best of their ability, and to try to get new members, because the more members they had the more good they could do.

A vote of thanks was accorded to the Committee of the Applied Science Department, University of Sheffield, for providing accommodation for the meeting.

At 3.20 an important discussion on Glass Refractories was initiated. The subject was introduced by a paper entitled, "The Properties of British Fireclays and their Suitability for Use as Glass Refractories. Part I," by Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc. The paper, illustrated by lantern-slides, was read by Dr. Turner.

After adjournment for tea, the discussion was resumed, and the following members took part:—Messrs. W. Butler, E. A. Coad-Pryor, J. Connolly, G. V. Evers, R. L. Frink, C. J. Peddle, W. J Rees, and the President. Dr. Turner replied.

The following members were elected:—

Collective Members.

Messrs. Pilkington Bros., Ltd.	Glass Works, St. Helens, Lancashire.
Messrs. Asahi Glass Co., Ltd. (Head Office)	Manufacturers of Window Glass, Refractory Materials, and Soda Ash, Marunouchi, Tokyo, Japan.
Messrs. Pickerdite & Co.	Glass Bottle Manufacturers, 1 & 2, Eagle Wharf Road, New North Road, London, N.
Messrs. Crystal Glass, Ltd.	58, Pitt Street, Sydney, N.S.W.

Ordinary Members.

S. N. Bose, M.A. (Calcutta).	c/o Messrs. Audittya Chandra Bose & Sons, 191, Old China Bazar Street, Calcutta, India.
William Graham.	Glass Bottle Worker, 6, Barton Buildings, Kinghorn, Fifeshire.
George Elmer Inman, B.S.	1876, Knowles Street, Cleveland, Ohio, U.S.A.
H. W. Oddin Taylor, A.C.G.I., B.Sc.	Industrial Engineer, 6, Colville Houses, Colville Square, London, W.11.
Hyoichi Sumida	Chemical Engineer, c/o Messrs. Asahi Glass Co., Ltd., Marunouchi, Tokyo, Japan.

Sanjiro Yamada.	Director, Messrs. Asahi Glass Co., Ltd., Marunouchi, Tokyo, Japan.
Koshav Balkrishna Vaidya, B. Com.	Secretary, The All India Industrial Syndicate, Ltd., and Rajaram Villa, Camp-Dadar, Bombay, No. 14, India.
Z. C. Kline, B.S.	Manager of Glass Factory, 801, Broad Street, Central Falls, Rhode Island, U.S.A.
A. T. Ridout.	Glassworks Manager, Messrs. British Glass Bottles, Ltd., Derby, and 162, Milcote Road, Smethwick.
R. M. Corl.	328, Bank of Commerce Bldg., Toledo, Ohio, U.S.A.
E. G. Johnstone.	c/o. Messrs. John Lumb & Co., Ltd., 12, Mark Lane, London, E.C.3.
G. G. Walker.	c/o. Messrs. John Lumb & Co., Ltd., 12, Mark Lane, London, E.C.3.
J. Paton.	General Manager, Messrs. The Dawson & Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
J. F. Greene, B.S.	Chemical Engineer, Messrs. Kimble Glass Co., Vineland, New Jersey, U.S.A.
J. Southerst.	Glass Bottle Manufacturer, Machine Glass Works, Farnworth, Nr. Bolton.
William M. Bishop.	Librarian, University of Michigan, U.S.A.

After the General Meeting, a special meeting was held of those interested in the proposed excursion to America in the autumn.

On Thursday, April 22nd, members had an opportunity of visiting two works, through the courtesy of their respective directors.

The first visit took place in the forenoon, when a party visited the Ickles Works, Sheffield, of Messrs. Steel, Peech and Tozer, Ltd. Here inspection was confined mainly to the working of a modern producer plant, while considerable interest was taken in the various labour-saving devices utilised.

In the afternoon the party, some 40 strong, proceeded by train to Barnsley. Here they were met by Mr. Frank Wood, who very kindly entertained the whole party to lunch, and in addition he arranged for the conveyance of members to the works of Messrs. Rylands Glass Engineering Co., Ltd., Stairfoot.

SECOND ANNUAL DINNER.

At 7 o'clock, following the Annual General Meeting, the Second Annual Dinner was held in the Royal Victoria Station Hotel, Sheffield.

The President, S. N. Jenkinson, Esq., M.B.E., was supported in the Chair by Sir W. H. Hadow (Vice-Chancellor of Sheffield University), Percy Ashley, Esq., C.B. (Assistant Secretary, Board of Trade), George E. Alexander, O.B.E., and Robert L. Frink (Chairman and Director, respectively, of the Glass Research Association), Frank Wood, Esq., C.B.E., and Dr. W. E. S. Turner, O.B.E. (Past-President and Secretary, respectively, of the Society), G. V. Evers (of Messrs. E. J. and J. Pearson, Ltd., Stourbridge), T. Mortimore Sparks (Commercial Editor of the *Sheffield Daily Telegraph*), and others.

The following were the toasts:—

I. "The King."

II. "The Society of Glass Technology." In proposing this toast, Sir Henry Hadow said that usually when one came to deal with an institution which stood for so much, either one could refer to its illustrious past or one could direct attention to the glorious future that lay before it. On this particular occasion, both courses lay open. The Society of Glass Technology could boast of a great past, and it also gave promise of a great future. He did not know whether it was generally reflected upon how some of the greatest inventions in the world had come about by accident. He did not know whether it was realised, for instance, that the first use of glass in Egypt was to glaze visiting cards, that were made of clay and left at the church. Nor was the history of the development of glass devoid of those chance and lucky accidents which mark an epoch-making event. Indeed, from the school books, he had gathered that the discovery of glass was wholly accidental; that certain Phœnician merchants, sitting down to cook their meal on a sandy shore, discovered a curious mass left behind by the fire, which had somehow acted on the materials of the beach, and, being traders, naturally decided that the glassy mass, for such it was, ought to have a commercial value.

But he would hurriedly pass over matters such as that, and concern himself with the prospects that lay before the glass industry in the future, with due co-operation and collaboration with scientific research. In referring to a matter of this sort, and. indeed, in dealing with the educational problem at all on that occasion, it was not his intention to beat the university drum or to grind the university axe. If societies which were concerned with technology or industrial research in any form found that they could do better without academic aid, then by all means let them. No institution had the slightest right to any consideration unless it showed that it could do its job. That was the one point which really mattered. At the same time, there was, as everybody knew, in the Sheffield University a Department of Glass Technology which was ready and willing and anxious to co-operate with industrial aims, and if it could be made of use, then it ought to be made of use. In estimating whether it could be made useful or not, there were two considerations he would like to put forward: one of these was that essentially every university department must fulfil three functions at one and the same time. It had got to train young people for the work of the next generation; it had got to answer questions, to assist in the solution of immediate problems in the age in which it lived; and it had got to research. Unless one had a department which was very fully equipped with apparatus and men of resource, there was rather a danger, especially in dealing with a young department which had got to feel its way and could not, from the nature of the case, be quite clear of its ground, of over-strain and over-pressure. The best way to solve that difficulty was to widen and strengthen the department so that it could delegate some parts of its work in this direction and in that, in order that the willing horse should not be bowed down by too heavy a burden. That was the first point that he wished to emphasise. The other of the two points which he wanted to make he could best illustrate by a rule-of-three sum which was once propounded by Lewis Carroll. If six men could build a house in five months, how many men could build a house in five minutes? There was an answer to such a sum, but when one got 50,000 men as the answer, and gave this as that theoretical number necessary to build the house in five minutes, one knew, all the same, that it could not be done. The thing did not work out in practice, for a very large proportion of the workmen would never get near the house at all, and would be none the less content, probably, on that account. When one came to deal with a department that was new and had got to feel its way, it must not be expected that the house should be built in five minutes. "Do not be too keen on getting immediate results," added Sir Henry. "Have a certain amount of patience. Scientific research is necessarily a long and sometimes a slow-moving process, but it gets there in the end. It is not good economy unnecessarily and unduly to hurry it. Get the best men. In some cases, I think, I may say quite safely that you have already got the best men. That being so, give them the best resources that you can and a free hand, and I am certain that not only the University will benefit, but, what is very much more important, glass technology will benefit. It is in the hope that this is coming about, in the hope that glass technology is going to have another four thousand years of progress in front of it—it has had four thousand already—and in the hope that it will advance and prosper in the future as much as it has done in the past, that I give you, with all possible pleasure, the toast of 'The Society of Glass Technology.'"

The President, in the course of his reply, said the Society was the link between science and the manufacturer.

III. "The Glass Research Association." In proposing this toast, Mr. G. V. Evers congratulated Sheffield University on being the first to instal a laboratory with the requisite appliances and staff for the scientific study of glass manufacture.

Mr. G. E. Alexander, O.B.E., replied. He referred to the work of the Association, and intimated that its intention was to place as much research work as possible with the Glass Department of Sheffield University, where Dr. Turner had accomplished so much in so short a time.

IV. "The Guests" were proposed by Mr. Frank Wood, C.B.E. He playfully twitted the Board of Trade on the red-tape character of its correspondence, but he admitted the great service it had rendered to the glass trade throughout the war. He coupled with the toast the names of Percy Ashley, Esq., C.B., and T. Mortimore Sparks, Esq.

Mr. Percy Ashley, C.B., in replying, observed that they were not anxious to control industry for the sake of any power that would arise from it. Rather, they were anxious to help manufacturers. If the latter would only co-operate more closely with the Government Department it would contribute materially towards building up British commerce to still greater heights.

Mr. T. Mortimore Sparks also responded.

V. "Our Secretary." In proposing this toast, Mr. Joseph Connolly remarked that in Dr. Turner they had a gentleman who had demonstrated to the full that science was organised common sense. This was proved by what he had done for the Society and for the glass industry.

Dr. Turner replied.

The following members and guests were present:—

Alderman, G.
Alexander, G. E.
Ashley, P.
Asquith, G.
Asquith, H. H.
Asquith, M.
Boam, F. J.
Branson, F. W.
Brown, A. G.
Bunniss, H.
Burdin, H.
Butler, W.
Butterworth, W.
Clark, F. G.
Clark, H. N.
Clark, Mrs. H. N.
Christmas, E. B.
Christmas, Mrs. E. B.
Coad-Pryor, E. A.
Connolly, J.
Connolly, Mrs. J.
Dale, W. R.

Davidson, J. H.
Dimbleby, Miss V.
Drake, F.
Dryden, H.
Dudding, B. P.
Duguid, C.
Duncan, G. S.
English, S.
English, Mrs. S.
Evers, G. V.
Firth, Miss E. M.
Frink, R. L.
Gardner, W. J., and Guest.
Gardner, S.
Giles, A. S.
Gloag, V. F.
Hadow, Sir W. H.
Heckels, J. S.
Higgins, J. T.
Hodkin, F. W.
Hodkin, Mrs. F. W.
Hodgson, R.
Holdsworth, Miss D.
Howes, H. W.
Jackson, Miss A. M.
Jenkinson, S. N.
Kelkar, G. D.
Meter, Van, W. L.
Morton, E.
Muirhead, Miss C. M. M.
Paterson, C. C. (Guest of).
Peddle, C. J.
Robertson, D.
Russell, E.
Sharp, E.
Sharp, R.
Sharp, T. W.
Smart, G. W.
Snowdon, W. C.
Southerst, J.
Sparks, T. M.
Styring, J. B.
Teisen, Th.
Tinkler, W.
Towers, C. E.
Towers, F. B.
Townsend, H.
Turner, W. E. S.
Turner, Mrs. W. E. S.
Varshnei, B. D.
Watts, J. W.
Way, G. W. W.
Whiteley, A.
Whitfield, J.
Wilson, D.
Wood, W. F. J.

(Total, 79.)

PROCEEDINGS OF THE THIRTY-FIFTH MEETING.

Held in the Institute of Chemistry, 30, Russell Square, London, W.C.1, on Wednesday, May 19th, 1920, at 2 p.m., the President, S. N. Jenkinson, Esq., in the Chair.

In connection with the election of members, Mr. Arnold Stevenson directed attention to Rule 5 of the Society's Constitution and Rules, whereby collective members had to be elected by ballot. The President said that election by the vote of meeting was adopted as it saved time. Mr. T. E. Wood, LL.B., who assisted in framing the rules, expressed the opinion that a vote by show of hands might be used where the rule referred to ballot. The Council, however, would consider the point further.

The President announced that several members were prevented from being present owing to having to attend important Manufacturers' Association meetings in Leeds.

Dr. Turner made a brief statement on the latest developments in regard to the American trip in the autumn.

A vote of thanks was accorded to the Institute of Chemistry for providing accommodation for the meeting.

A welcome was extended to members of the Faraday, Optical, and Physical Societies who were present, an invitation to the meeting having been sent to members of these societies who resided in or near London.

The President also gave a hearty welcome to Mr. K. E. Ostlund, a Swedish member of the Society, and President of the Federation of Swedish Glass Manufacturers. In welcoming Mr. Ostlund, Mr. Jenkinson said that they were an international and cosmopolitan Society. Some two years previously Dr. Turner had raised the question of starting a branch of the Society in Scandinavia, so as to receive papers and information affecting the glass industry in that part of the world and form a closer link than existed at present. A proposal had also been made to have a tour of Swedish glass works, or to have Swedish members visit glass works in Britain. Swedish manufacturers, said Mr. Jenkinson, took a very broad view. "Live and let live" was their motto. They were not averse to teaching their competitors something, realising that by so doing they would themselves learn something in return.

Mr. K. E. Ostlund, who was received with acclamation, said that he was very glad to be present and to visit his English colleagues. He hoped they would all work well together. He regretted that his limited knowledge of English prevented his speaking at greater length.

The principal business of the meeting was a General Discussion on "The Physical Properties of Glass." The discussion was opened by Mr. C. J. Peddle, M.Sc., F.I.C., who gave an account of the development of glasses for optical purposes. The following papers were taken as read:—

1. "The Development of Various Types of Glass," by C. J. Peddle, M.Sc., F.I.C.
   Part I. "The Interaction of Silica with the Oxides of Sodium and Potassium."
   Part II. "The Interaction of Silica, Lime, and Sodium Oxide."
   Part III. "The Interaction of Silica, Lime, and Potassium Oxide."
   Part IV. "The Interaction of Silica, Lime, and the Oxides of Sodium and Potassium."
   Part V. "A Comparison of the Soda-lime–Silica and the Potash–Lime–Silica Glasses."
2. "The Thermal Expansion of Magnesia-containing Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.
3. "The Optical Properties of some Lime-soda Glasses," by J. R. Clarke, M.Sc., and W. E. S. Turner, D.Sc.
4. "The Annealing Temperatures of Soda-lime and Soda–Magnesia Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.
5. "The Durability of Lime-soda Glasses," by J. D. Cauwood, M.Sc., J. R. Clarke, M.Sc., Miss C. M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.
6. "The Influence of Lime on the Value of Young's Modulus of Elasticity for the Lime-soda Glasses," by J. R. Clarke, M.Sc., and W. E. S. Turner, D.Sc.
7. "The Density of Soda–Magnesia Glasses and a Comparison with that of the Soda-lime Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.

Mr. Peddle's communication elicited a lively discussion, in which there took part the President, Dr. W. E. S. Turner, Dr. W. Rosenhain, and Messrs. W. L. Baillie, E. A. Coad-Pryor, B. P. Dudding, R. L. Frink, W. E. Oakden (a visitor), and V. H. Stott. Mr. Peddle replied.

A hearty vote of thanks was accorded to Mr. Peddle for his paper.

Dr. M. W. Travers, F.R.S., then gave a short paper entitled, "A Surface Effect in Glass, probably caused by re-heating." Two specimens of glass were exhibited. Dr. W. Rosenhain, Mr. R. L. Frink, and the President joined in the discussion that followed. Members were invited to send to Dr. Travers specimens of interest.

The following members were elected:—

Collective Members.

The Glass Research Association.	50, Bedford Square, London, W.C.1.
Messrs. Gregg & Co.	Glass Bottle Manufacturers, Hope Glass Works, Knottingley, Yorks.
Messrs. King, Taudevin & Gregson, Ltd.	Consulting Engineers and Furnace Builders, Melbourne Chambers, Cambridge Street, Sheffield.
Messrs. J. W. Sutcliffe & Co.	Glass Bottle Manufacturers, 52, Queen Victoria Street, London, E.C.4.
Messrs. Campbell Brothers.	Glass, Oil and Colour Merchants, 19, 21, & 23, Franklin Street, Belfast.

Ordinary Members.

Frederick William Adams, M.Sc.	Rockware Glass Syndicate, Greenford, Middlesex.
William Atack.	52, Pottery Street, Whitwood Mere, Castleford.
Harold Bunniss.	Manager, Aldham Glass Works, Wombwell.
William Galbally.	General Factory Superintendent, c/o Messrs. Cannington Shaw & Co., Ltd., St. Helens, Lancs.
Phauindra Nath Ghosh, M.A.	Lecturer in Optics, University College of Science, Calcutta.
Miss Doris Holdsworth, B.Sc.	Research Assistant, Dept. of Glass Technology, University, Sheffield, and 151, Rock Street, Pitsmoor, Sheffield.
Thomas Courtney Moorshead, Mem. Am. Soc. Civil Engrs.	Technical Adviser, Messrs. British Glass Industries, Ltd., and c/o Messrs. United Glass Bottle Manufacturers, Ltd., 195, Strand, London, W.C.2.
Hu Wei Pai.	Department of Glass Technology, University, Sheffield.
James Seddon, Lieutenant (Late R.E.), A.M.I.Mech.E.	c/o Messrs. British Glass Industries, Ltd., 2, Central Buildings, London, S.W.1.
Norman Shaw.	c/o Messrs. Shaws (Huddersfield), Ltd., Fruit Preservers, &c., Storths Mill, Mold Green, Huddersfield.
Alfred Wilson.	Gas Furnace Engineer, 35, Doxey, nr Stafford.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING.

HELD in the Mappin Hall, Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, June 16th, 1920, at 2.15 p.m., MR. J. CONNOLLY, Vice-President, in the Chair.

At 2.15 p.m. a Special General Meeting was held, when a Resolution was carried unanimously to amend the last sentence of Rule 20 so as to read:—"The Council shall consist of the President, Past-Presidents, twelve Vice-Presidents, *the General Treasurer, the American Treasurer*, Secretary, and Assistant Secretary, and fifteen members, who shall be elected at the Annual General Meeting." The alteration consisted in substituting the words in italics for the words *the Treasurer.*

At 2.20 p.m. the Ordinary General Meeting was held.

MR. CONNOLLY intimated that a Testimonial was being raised by the Refractories Association for Mr. Rees in connection with the forthcoming visit of the Society to America in the autumn. Mr. F. J. Boam had reported that a sum of over £150 had already been subscribed, and Mr. Frank Wood, of Barnsley, had informed Prof. Turner that his firm, Messrs. Wood Bros. Glass Co., Ltd., would be glad to subscribe ten guineas through the Society. The Chairman said that further contributions would be welcomed.

It was announced that a visit of the Society was being arranged for the middle of July to Messrs. Boam's sand pits at King's Lynn. Detailed programmes would be issued later.

The CHAIRMAN intimated that the party proposing to make the excursion to America in the autumn now numbered 36, and that arrangements were being completed on the other side of the Atlantic to give its members a warm welcome.

It was resolved unanimously that the Secretary be asked to convey a very cordial invitation to the members of the American Ceramic Society to a united Conference in England in 1922.

A hearty vote of thanks was accorded to the Committee of the

Applied Science Department of The University, Sheffield, for providing accommodation for the meetings of the Society.

A resolution was carried with acclamation to the effect that a message of congratulation be sent to Dr. W. E. S. Turner on receiving the title of Professor from the University of Sheffield.

In speaking for the resolution, Mr. J. Connolly said that no words of his were needed in its support. In fact, they all felt elevated along with Prof. Turner, and they shared with him his new honour.

The following paper was taken as read:—

"Some Notable Effects of Alumina on the Properties of Glass." By S. English, M.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

A very interesting lecture was then given on "The Human Factor in Industry," by George H. Miles, D.Sc., of the National Institute of Psychology and Physiology Applied to Commerce and Industry. A discussion followed, in which there took part Messrs. A. S. Giles, E. A. Coad-Pryor, C. J. Peddle, W. Butterworth, jun., Miss F. H. A. Turner (visitor), and the Chairman, Mr. J. Connolly. Dr. Miles replied.

On the suggestion of Mr. E. A. Coad-Pryor, it was resolved that the attention of the Glass Research Association be directed to the psychological aspects of the glass industry, and that the Glass Research Association be asked to communicate with the National Institute of Psychology and Physiology on the subject.

The meeting concluded with a resolution which conveyed a message of sympathy to Prof. W. E. S. Turner, who was unable to attend owing to indisposition.

The following members were elected:—

Ordinary Members.

Robert Adamson	Glass Works Furnace Manager, Rockware Glass Syndicate, Greenford, Middlesex.
Archibald Alison	Engineer, 35, Gleneldon Road, Streatham, London, S.W. 16.
John Currie, M.A.	Works Chemist, Messrs. Scottish Central Glass Works Ltd., Alloa.
Charles Duguid,	Banker, Park Lodge, New Barnet, and Commercial Bank of London, Austin Friars, London, E.C. 2.
James William Barker	Engineer, Messrs. Stein & Atkinson, 47 Victoria Street, Westminster, London, S.W. 1.
Leo Rabinovitch, D.Sc.	Consulting Engineer and Chemist, Messrs. Cosmos Lamp Works, Ltd., Brimsdown.

William Robinson	Manager, Messrs. Alperton Glass Works, Middlesex.
Roy Sinclair Smith	Chemist, Messrs. Australian Glass Manufacturers' Co., Ltd., Sydney.
Howard J. Tait, B.A., B.Sc.	Messrs. Phœnix Glass Co., Monaca, Pa , U.S.A.
Thomas Wardley	Engineer, Messrs. British Hartford-Fairmont Syndicate, 142, Audrey House, Ely Place, London, E.C. 1.
Albert J. Walcott, M.Sc.	Messrs. Bausch & Lomb Optical Co., Rochester, N.Y., U.S.A.
Tosaku Yoshioka	Assistant Professor of Chemical Technology, Imperial University, Kioto, Japan.
William Anton Yung, B.S.	Chemical Engineer, Edison Lamp Works of General Electric Co., Harrison, N.J., U.S.A.
George William Ballans	Glass Worker, Department of Glass Technology, The University, Sheffield.

Student Members.

William Francis Pearson	Charles Street, West Bromwich.
John Alfred Mitchell-Withers	14, Oakholme Road, Sheffield.

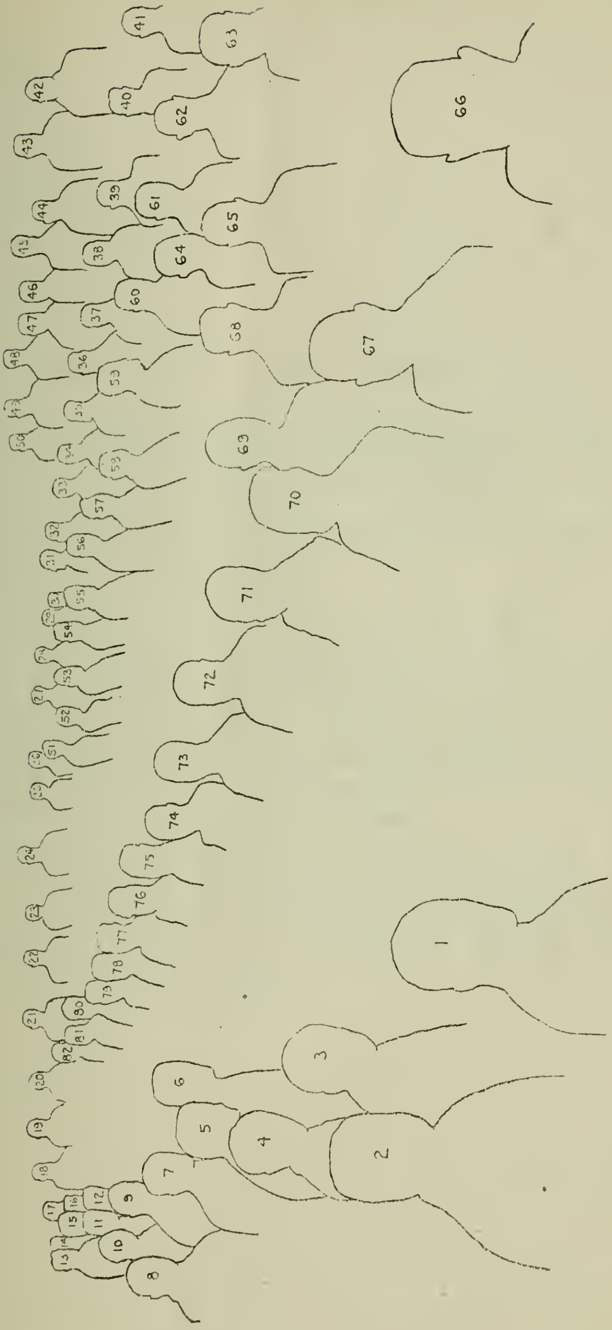
OBITUARY NOTICE.

We regret to record the death, on July 15th, 1920, of Mr. Alexander Barron, the Managing Director of Messrs. Thos. Barron, Ltd., of the Phœnix and Don Glass Works, Mexboro. Mr. Barron, who was sixty-nine years of age, was a well-known figure in the glass industry of South Yorkshire, entering at the age of ten into his father's factory, and continuing from that time for practically sixty years in some position in the industry. His experience was by no means confined to Mexboro, for in 1904 he went out to South Africa to manage a factory owned by the Cape Glass Co. at Simonstown, near Capetown. Returning to England after eighteen months spent in South Africa, he undertook the management of the Edmonton Glass Bottle Works, London, until 1910, when he returned to Mexboro to resume his place in the management of the Phœnix and Don Glass Works. From that time until his death he served as Managing Director of Messrs. Thos. Barron, Ltd.

Mr. Barron undertook a considerable amount of public work having been a member of the Mexboro Local Board, the Burial Board, and the Doncaster Board of Guardians. During the war he was prevailed upon in some measure to return to public life, and served on the Recruiting Tribunal, the War Pensions Committee, the Employment Committee, the War Relief Committee, and the War Memorial Committee.

Mr. Barron was one of the original members of the Society of Glass Technology, and was very strongly impressed with the need of bringing science to bear on the glass industry. In his own locality he served as a Vice-President of the Mexboro Glass Technology Society, and was always ready to encourage young men to take up the study of glass-making from the scientific side.

COMPLIMENTARY BANQUET
TO
SOCIETY OF GLASS TECHNOLOGY OF ENGLAND
TENDERED BY
THE GLASS DIVISION AMERICAN CERAMIC SOCIETY
WILLIAM PENN HOTEL SEP 3, 1920.
Trinity Court Studio



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INAUGURAL LUNCH—SESSION 1920–21.

Prior to the opening meeting of the new session, members of the Society and their guests met together for social intercourse at a lunch held at the King's Head Hotel, Sheffield, at 1.15 p.m. on Wednesday, October 27th, 1920.

The party numbered 41, and included many of those who had recently paid a visit to America.

The following were the toasts:—

1. "The King." Proposed by Dr. C. J. Peddle.
2. "The Pilgrims." Proposed by Dr. C. J. Peddle, who welcomed back to the fold those members of the Society who had taken part in the American trip. Mr. A. L. Foster replied.
3. "The Glass Division of the American Ceramic Society." In proposing this toast, Mr. W. J. Rees coupled with it the name of Mr. Robert L. Frink. Mr. Frink replied.

The lunch ended with a vote of thanks, proposed by Prof. W. E. S. Turner, to Mr. H. Johnson (of Messrs. Thos. Cook and Sons), who had rendered valuable services in arranging for booking berths and in other ways in connection with the American excursion. Mr. Johnson replied.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING.

Held in the Metallurgical Lecture Room, Applied Science Department, The University, St. George's Square, Sheffield, on Wednesday, October 27th, 1920, at 2.45 p.m., Mr. W. Butler in the Chair.

The Chairman, in the name of the Society, gave a welcome to those members of the Society who had recently returned from a visit to America. The meeting was not so large as they would have liked, but it was good that so many were present, considering the adverse industrial conditions under which the country suffered owing to the coal strike. (Dr. Peddle here observed that it was one of the biggest meetings they had held.)

Continuing, the Chairman said that they were there to welcome pilgrims who had gone to see the wonders of America.

The following then spoke on the subject before the meeting, "Lessons from the Visit to America":—Prof. W. E. S. Turner, Messrs. W. J. Rees, G. P. Gass, H. N. Clark, W. B. Mitchell, H. A. Bateson, H. Gregg, W. C. Snowdon, A. L. Foster, R. L. Frink, and the Chairman.

The following twenty-eight members were elected:—

(*a*) *Collective Members.*

Société Anonyme des Verreries d'Aigues-Mortes.	Gard, France.
Messrs. Australian Glass Manufacturers' Co., Ltd.	Spotswood, Victoria, Australia.
Messrs. Aylesford Sand Co., Ltd.	Sand, Flint and Gravel Merchants, 16, Water Lane, Great Tower Street, London, E.C.3.
Messrs. Geo. Bray & Co., Ltd.	Gas Lighting Engineers, Leeds.
Messrs. Dennistoun Glass Works, Ltd.	Manufacturers of Glass Bottles and Jars, 174, Glenpark Street, Dennistoun, Glasgow.
Messrs. The Western India Prospecting Syndicate Ltd.	Cawnpore, India.
Société Industrielle de Verrerie.	56, Rue Laffitte, Paris, France.

(*b*) *Student Member.*

Arthur Renwick Sheen.	Department of Glass Technology, The University, Sheffield, and 13, St. Gabriel's Road, Cricklewood, London, N.W.2.

(*c*) *Ordinary Members.*

J. Antonio de Artigas, Dr. Sc., Dr. Ing., Knight of the Order Charles III.	4, Arrieta, Madrid, Spain.
Arthur J. Bennett, President Cambridge Glass Company.	519, North 7th Street, Cambridge, Ohio, U.S.A.
William Henry Brookes, Glass Bottle Works Manager.	Union Glass Works, Talana, Natal, South Africa.
George W. Cooper, Publisher.	19, Liberty Street, New York City, N.Y., U.S.A.
Algernon Lewin Curtis, Late Lieut. R.A.F.	39, London Road, Chatteris, Cambridgeshire.
Carl Gottwald Sven Harald Fogelberg, Assistant Director.	Kosta Glassworks, Sweden.
Edwin Levi Hettinger, Assistant Secretary and Purchasing Agent.	1325, Mineral Spring Road, Reading, Pa., U.S.A.
John Clyde Hostetter, Ph.D., Manager.	Steuben Division, Corning Glass Works, Corning, N.Y., U.S.A.
J. G. Kaufman, Manager.	"The Glassworker," Box 555, Pittsburgh, Pa., U.S.A.
Joseph Mandefield.	26, Gressenhall Road, Southfields, London, S.W.18, and Department of Overseas Trade, London.
Geoffrey Isidore Charles Marchand, M.A., Managing Director's Assistant.	British Glass Industries Ltd., 195, Strand, London, W.C.2.
William Henry Mayhew, Sub-Manager.	Messrs. Chance Bros. & Co., Ltd., Smethwick, Birmingham.
Harold Charles Metzgar, Constructional Engineer.	39, Babington Road, Streatham, London, S.W.16, and 2, Central Buildings, Westminster, London, S.W.1.
Seiji Nakamura, Professor of Experimental Physics.	Physical Institute, Imperial University, Tokyo, Japan.
Michael Parkin, B.Sc., Research Assistant and Demonstrator.	Department of Glass Technology, The University, Sheffield.
Dale D. Schurtz, Glass Chemist.	The Sharp-Schurtz Company, Lancaster, Ohio, U.S.A.
Vaughan Husband Stott, M.Sc., Research Chemist.	National Physical Laboratory, Teddington, Middlesex.
Maurice M. M. Thouvenin, Glass Manufacturer.	Verrerie de Vierzon, Vierzon-Forges, Cher, France.
Frank H. Wheaton, Glass Bottle Manufacturer.	Millville, N. J., U.S.A.
Bert Carpenter, Glass Worker.	4, Coniston Road, Barnsley, and Messrs. Wood Bros. Glass Co., Ltd., Barnsley.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING.

HELD in the Lecture Room of the Coal, Gas, and Fuel Industries Department, The University, Leeds, on Wednesday, November 17th, 1920, at 2.30 p.m., the President, S. N. JENKINSON, Esq., in the Chair.

At 2.30 a SPECIAL GENERAL MEETING was held, at which it was resolved to amend Rule 5 so as to read:—

> "Every candidate for admission as a Collective Member shall be proposed by the Council at any ordinary meeting of the Society. A two-thirds majority shall be necessary for election."

The amendment consisted in the omission after the word "Society" of the words *and the election shall be by ballot at such meeting.*

The ORDINARY GENERAL MEETING followed. Prior to the presentation of the papers on the agenda, a vote of thanks was accorded to the authorities of the University of Leeds and to Prof. Cobb for providing accommodation for the Society's meetings.

The first paper to be given was "The Reversible Thermal Expansion of some Fireclays and other Refractory Materials," by H. S. Houldsworth, M.Sc., and Prof. John W. Cobb, C.B.E., B.Sc., F.I.C. The paper was illustrated by lantern-slides, and was followed by a discussion, to which the President, Prof. Turner, and Mr. W. Butler contributed. Prof. Cobb, who gave the paper, replied.

The second paper was taken as read, viz., "The Nomenclature of Glasses," by C. J. Peddle, D.Sc., F.I.C.

The third paper, entitled "Alumina in Glass," by S. English, M.Sc., A.I.C., F. W. Hodkin, B.Sc., A.I.C., and Prof. W. E. S. Turner, D.Sc., was given by the latter. Mr. E. A. Coad-Pryor contributed to the discussion that followed. Specimens of lamp-worked alumina–soda glass were exhibited.

The last paper on the agenda was "The Effect of added Felspar on the Shrinkage and Porosity of Fireclays after being Fired at High Temperatures," by Edith M. Firth, B.Sc., and W. E. S. Turner, D.Sc. This paper was given by Prof. Turner.

The meeting concluded with a vote of thanks to the authors of the papers.

The following members were elected:—

(*a*) *Ordinary Members.*

Hubert Spencer Blackmore.	74, Kendal Road, Hillsborough, Sheffield, and Student in Glass Technology, University of Sheffield.
Hitkaran Nath Misra, B.Sc., Student.	Department of Glass Technology, The University, Sheffield.
Emerson P. Poste, B.Sc., Chemical Engineer.	The Elyria Enameled Products Co., Elyria, Ohio, U.S.A.
Henry Smith, Glass House Pot Maker.	27, Tillie Street, Kelvinbridge, Glasgow.
Henry Daniel Herdt, B.Sc., Glass Manufacturer	Messrs. Dominion Glass Co. Ltd., 285, Beaver Hall Hill, Montreal, Canada.

(*b*) *Student Member.*

Lionel Etridge Norton.	46, Woodberry Down, Finsbury Park, London, N.4, and Student in Glass Technology, University of Sheffield.

The Society's Visit to America.

The party of members of the Society which left Liverpool on board the Furness-Withy liner "Fort Victoria" on August 14th was comprised of Messrs. Edward Allan, H. H. Asquith and Mrs. Asquith, W. Atack, H. A. Bateson, C. W. Burtles, W. Butterworth, jun., H. Noel Clark and Mrs. Clark, A. Dodds, F. Drake, Sven Fogelberg, A. L. Foster, C. T. Garbutt, G. P. Gass and Miss Gass, A. S. Giles, H. Gregg, R. Hodgson, H. S. Jessop, A. R. Jessop, Wm. Lamont, W. B. Mitchell, G. P. Ogale, W. J. Rees, W. C. Snowdon, T. C. Sutcliffe, C. E. Towers, Prof. W. E. S. Turner, B. D. Varshnei, Duncan Webb, jun., and J. Woolford.

Mr. and Mrs. Julian Osler joined the party in Pittsburgh.

The party landed at Boston on Monday, August 23rd, and travelled by boat the same night to New York, where they were met and welcomed by Mr. Jules Dierckx, Mr. Wm. Noble, and other friends, acting on behalf of a New York Committee, of which Mr. C. H. Tiebout was chairman.

This committee most royally entertained the visitors to dinner on the roof garden of the Hotel Waldorf-Astoria and at a subsequent performance at the New York Hippodrome, in addition to taking them for a motor tour to see New York. Visits were paid on the morning of August 25th to the works of Messrs. Westinghouse Electric Lamp Co. under the guidance of Dr. A. Brann, to the Automatic Mould Cutting Machinery Co. with Mr. Jules Dierckx, and to a variety of other places.

Mr. Herman Kimble was responsible for arranging for the transit of the visitors from New York to Vineland. *En route* to this place they were met and welcomed by Mr. Herbert Walls, who had taken a prominent part in all the arrangements for entertainment and visitation at Vineland and neighbourhood. In Vineland the members of the party were guests at lunch of Messrs. Kimble Glass Co. on Thursday, August 26th, and were entertained to a most delightful banquet in the evening of the same day by the City Chamber of Commerce in Vineland, the President, Capt. Hood, opening the proceedings, the Toastmaster being Judge

Tuller. The speakers at the banquet were Mr. Frank Channon, Dr. W. E. S. Turner, Messrs. Ralph Barber, J. Woolford, H. B. Sayford, Reuben Hodgson, Dr. Tillotson, G. P. Ogale, Capt. A. S. Giles, C. E. Towers, and Herbert Walls.

Visits were paid in Vineland to Messrs. Kimble Glass Co. and the Minotola works of the Cumberland Glass Co., Messrs. Vineland Flint Glass Co., and the Vineland Scientific Glass Co., whilst individual members of the party paid a series of visits to other works in the neighbourhood.

On Thursday, August 27th, the party proceeded to Philadelphia, and after a few hours' stay journeyed by night to Pittsburgh, the arrangements for transit having been made by Dr. A. Brann.

The party had had the very good fortune to meet Dr. E. W. Tillotson in New York, he being deputed by the American Ceramic Society to act as official guide throughout the visit. Not only did Dr. Tillotson's untiring efforts relieve the party of responsibility for their further journeys, but his modest and cheerful personality endeared him to every member.

The party was met at Pittsburgh by Mr. H. L. Dixon and other friends and escorted to the Hotel Schenley. It was found on arrival that arrangements had been made for temporary membership for each member of the party at the University Club, the Pittsburgh Athletic Association Club, the Pittsburgh Chamber of Commerce Club, the Duquesne Club, and the Americus Republican Club.

During the course of the Saturday a visit of inspection was made to the Mellon Institute, whilst in the afternoon the whole of the party attended a baseball match.

The main items in the stay at Pittsburgh and of the visits to other centres may be summarised as follows:—

August 29th.—A motor-car trip of upwards of 60 miles to see the neighbourhood of Pittsburgh.

August 30th.—Visits to the McKee Glass Co., Jeannette, the Jeannette Works of the American Window Glass Co., and the Jeannette Glass Novelty Co.

August 31st.—Visits to the Hazel-Atlas Glass Co. at Washington, Pa., and the Findlay Clay Pot Co., the Allegheny Plate Glass Co. at Glassmere, and the Atlantic Bottle Co.

September 1st.—Visits to the Laclede-Christy Clay Products Co. at Rochester in the morning, and to the Phœnix Glass Co., Monaca, in the afternoon. The members were guests to lunch at the Welcome Club, Rochester, of the H. C. Fry Glass Co., Mr. W. J. Rees proposing a toast to the hosts at Rochester who so kindly welcomed the visitors. In the evening the members were the guests of Mr. H. L. Dixon at the Americus Republican Club, Pittsburgh. Mr. H. Dixon, jun., proposed the toast of the visitors, and Dr. Turner and Mr. J. Woolford replied.

At 7.0 p.m. a Smoker was held under the chairmanship of Mr. W. M. Clark in the hall of the Pittsburgh Chamber of Commerce, and a lecture was given by Mr. Chapman, of the Chapman Producer Co., on "The Development of the Modern Gas Producer," and a paper was read by Mr. J. F. Denk on "Low Grade Gas."

Mr. H. L. Dixon, Mr. Rees, and Dr. Turner took part in the discussion of the lecture. A cinematograph display concluded the proceedings.

September 2nd.—Visits to the Heinz Pickle Factory, where the party was entertained to lunch, and in the afternoon to the United States Glass Co., the D. O. Cunningham Glass Co., and the Willetts Glass House Refractories Co. at Pittsburgh. At night the two Societies held a joint session under the chairmanship of Dr. S. R. Scholes for the reading and discussion of the following papers:—

Dr. A. Silverman, "Similarity between Vitreous and Aqueous Solutions"; "Microscopic Illumination."

Dr. E. L. Hettinger, "Development of Transparent Coloured Glasses in America within Recent Years."

Dr. J. C. Hostetter and Dr. H. S. Roberts, "Notes on the Dissociation of Ferric Oxide dissolved in Glass and its Relation to the Colour of Iron-bearing Glasses."

W. J. Rees, "Provisional Specification for Refractory Materials."

Dr. C. J. Peddle, "The Nomenclature of Glass."

Dr. W. E. S. Turner, (1) "The Necessity for the Revision of the Physical Data of Glass obtained by the Workers of the Jena School"; (2) "Some Notable Effects of Alumina on Glass."

Dr. S. R. Scholes, "The Function of Arsenic in Glass Making."

September 3rd.—In the morning visits were paid to the W. J. Miller Machine Co., Swissvale, Pa., and the Pittsburgh Lamp, Brass, and Glass Co.

The party were guests at a lunch given by the Pittsburgh Chamber of Commerce.

During the afternoon further visits were paid to works, namely, Messrs. J. T. and A. Hamilton and Pittsburgh Clay Pot Co.

At night the Glass Division of the American Ceramic Society gave an official banquet to the visitors at the William Penn Hotel, Dr. S. R. Scholes presiding, and Mr. H. L. Dixon being Toastmaster. Mr. John S. Herron (President of Council, City of Pittsburgh) and Dr. Samuel B. McCormick (Chancellor, University of Pittsburgh) spoke on behalf of the hosts, and Dr. Turner and Mr. Julian Osler replied for the guests.

September 4th.—A visit was paid to the Sharpsburg bottle works of the H. J. Heinz Co. At night Mr. H. L. Dixon entertained the male members of the party to dinner at the Pittsburgh Athletic Association.

September 5th.—A dinner was given by Mr. G. P. Gass to the ladies of Pittsburgh who had made the stay so pleasant for the lady members of the party. Several of the prominent men amongst the hosts and amongst the visitors were also present.

September 6th.—In the morning the visitors watched the various processions and celebrations attendant on Labour Day, and some attended a baseball match in Pittsburgh. At the close of the afternoon a reluctant farewell was said to Pittsburgh and many friends there. The main party left by special cars for Fairmont. Two or three other members had made arrangements for special visits, and now set out on their own travels or joined the party at a later stage.

September 7th.—At Fairmont the visitors were received by Dr. R. R. Shiveley, who had made all arrangements for the stay. Visits were paid to the Monongah Glass Co., the Owens Bottle Co., and the Willetts Glasshouse Refractories Co. A very pleasant time socially was also spent at Fairmont.

September 8th.—In the morning the party left Fairmont for Clarksburg, where they visited the Travis Glass Co. and the Clarksburg Glass Co. Three members of the party also had the pleasure of meeting the American Ambassador to England at the Clarksburg Rotary Club.

September 9th.—Owing to train delay, the visitors arrived rather late at Charleston, and the visits to the Libbey-Owens Sheet Glass Co. and the Owens Bottle Co. in Charleston had to be hurried. This was much regretted, especially in view of the preparations for a great welcome made by the local committee. The party left for Columbus later in the morning.

September 10th.—At Columbus a visit was paid to the Federal Glass Co., after which the party left for Toledo.

September 11th.—The arrangements at Toledo had been made by Mr. H. Hess, and, in addition to the visits to works, the facilities for golf and the entertainment provided made the stay over Saturday and Sunday very enjoyable. Visits were paid on the Saturday to the following works:—The Modern Glass Co., the Buckeye Clay Pot Co., the Libbey Glass Manufacturing Co., and the Owens Bottle Co.

September 12th.—In the evening of Sunday, September 12th, the party left for Muncie, Indiana.

September 13th.—An excellent programme had been arranged by Mr. C. O. Grafton, of Messrs. Gill Clay Pot Co. Visits were paid to the following works in Muncie:—The Gill Clay Pot Co., Ball Bros. Co., and the Hemingray Glass Co.

In the evening the party left for Buffalo *via* Cleveland, Ohio.

September 15th.—The party left Buffalo on a visit to the Corning Glass Works and the Steuben Glass Works. At Corning, during an interval in the programme, the opportunity was taken of presenting to Dr. E. Ward Tillotson a little gift, not only as a memento of a very special occasion, but also in recognition both of his untiring efforts to make the visit a success and of his own personal worth, which had endeared him to every member. The gift was one of English glass table-ware. Capt. Giles made the presentation speech.

In the evening the party returned to Buffalo.

September 16th.—The party spent the day, or part of the day, at Niagara Falls, and afterwards separated. Some continued a tour right across Canada and America; others were spending one, two, or more additional weeks in Canada or the United States. Others, in turn, made their way in small groups to Montreal. The visits to works in Canada, namely, to the various factories of the Dominion Glass Co. and to the Consumers' Glass Co. in Montreal, were largely unorganised, and were made by members at their own convenience. Much kindness was shown to the visitors by representatives of both these firms.

Two members of the party, Messrs. C. Burtles and Duncan Webb, left Montreal for home very suddenly on Wednesday, September 15th, the former being summoned by cable owing to the death of Alderman Burtles.

The main party, reduced to eleven in number, sailed home from Montreal by the "Metagama" on September 18th. The second party of eight left Montreal on September 25th by the "Corsican." Both parties had rather rough weather, but enjoyed themselves greatly nevertheless. On the "Metagama" the Secretary was greatly honoured one night at a complimentary dinner given by the other members of the party, the menu being:—Mixed Cullet; Ruby and White Flint; Pot Ladings and Alkali; Floating Agitator; Firebrick well fired with Natural Gas and Batch; Dragadings and Wet Saltcake; Manganese, Selenium, and Uranium; Cold Air Douche *à la* Dr. Turner; Sum'at to Sup *à la* Gregg; Allan Waters.

Other members of the party made their way home by various routes, Messrs. Ogale and Varshnei, however, remaining behind, having taken up connections with glass firms in the United States.

A very happy sequel to the visit took place on Wednesday, December 8th, when a Reunion was held at the King's Head Hotel, Sheffield. Dr. and Mrs. Turner were present as guests at the dinner, presided over by Mr. A. Dodds, and were overwhelmed with surprise at the magnificent gift of notes, to the value of £175, from the members of the party which went to America. Mr. G. S. Duncan, the Assistant Secretary, was also given a present of £10. Many kind things were said all round, not spoken lightly but fully meant, our American friends were recalled and toasted, men and women, and throughout there prevailed a spirit of goodwill which ought to be a tower of strength, during the lean times, to the friendships made during a memorable tour.

LIST OF PEOPLE ATTENDING BANQUET OF THE AMERICAN CERAMIC SOCIETY AND THE SOCIETY OF GLASS TECHNOLOGY.

1. Thomas McCreary, Phœnix Glass Co., Monaca, Pa.
2. William P. Clark, Toledo, Ohio.
3. J. Woolford.
4. E. Allan.
5. A. Dodds.
6. R. Hodgson.
7. Wm. J. Miller, Swissvale, Pa.
8. T. F. Emminger, Pittsburgh Clay Pot Co., Pittsburgh, Pa.
9. A. E. Gray, Pittsburgh Clay Pot Co., Pittsburgh, Pa.
10. A. W. Kimes, National Glass Budget, Pittsburgh, Pa.
11. William Lamont.
12. C. T. Garbutt.
13. C. D. McArthur, Blaw Knox Co., Pittsburgh, Pa.
14. G. P. Ogale.
15. C. L. Sharp, Lancaster, Ohio.
16. G. H. Willetts, Pittsburgh, Pa.
17. A. H. Hoodman, Blaw Knox Co., Pittsburgh, Pa.
18. Julian Osler.
19. Dr. W. E. S. Turner.
20. Dr. S. B. McCormick, Chancellor, University of Pittsburgh, Pittsburgh, Pa.
21. H. L. Dixon, Pittsburgh, Pa.
22. Dr. S. R. Scholes, Utility Glass Co., Lonaconing, Md.
23. C. W. Brown, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
24. J. S. Herron, President Pittsburgh Council.
25. Mrs. H. L. Dixon.
26. Miss Gass.
27. Mrs. J. R. Johnston, Jr.
28. Mrs. H. G. Dixon.
29. Mrs. H. N. Clark.
30. Mrs. Osler.
31. G. P. Gass.
32. W. A. Yung, Westinghouse Lamp Works, Harrison, N.J.
33. Dr. E. W. Tillotson, Mellon Institute, Pittsburgh, Pa.
34. H. W. Seldon.
35. H. O. Pringle.
36. H. J. White, H. L. Dixon Co., Pittsburgh, Pa.
37. T. F. Harnack, H. L. Dixon Co., Pittsburgh, Pa.
38. C. R. MacCann, H. L. Dixon Co., Pittsburgh, Pa.
39. V. G. Greene, Swissvale, Pa.
40. R. M. Kimball, Pittsburgh, Pa.

41. T. A. Kimes, National Glass Budget, Pittsburgh, Pa.
42. E. B. Gillinder, Philadelphia, Pa.
43. C. D. Spencer.
44. A. D. Terry, Secretary, Chamber of Commerce, Pittsburgh, Pa.
45. Dr. J. C. Hostetter, Steuben Glass Works, Corning, New York.
46. S. Stafford, Pittsburgh, Pa.
47. A. H. Chandler, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
48. J. R. Johnston, Jr., Pittsburgh, Pa.
49. C. H. Blumenauer, Jefferson Glass Co., Follansbee, W. Va.
50. H. G. Dixon, H. L. Dixon Co., Pittsburgh, Pa.
51. Mrs. H. H. Asquith.
52. Mrs. T. F. Harnack.
53. L. W. Nichols, Pittsburgh Plate Glass Co., Charleroi, Pa.
54. W. S. Williams, H. C. Fry Glass Co., Rochester, Pa.
55. W. J. Rees.
56. D. W. Ross, Findlay Clay Pot Co., Washington, Pa.
57. C. E. Fulton, Pittsburgh Plate Glass Co., Creighton, Pa.
58. Prof. C. W. Parmalee, University of Illinois, Urbana, Ill.
59. Wm. M. Clark, Nela Park, Cleveland, Ohio.
60. George J. Eibel, National Glass Budget, Pittsburgh, Pa.
61. W. C. Snowdon.
62. H. A. Bateson.
63. Louis Reizenstein, Pittsburgh, Pa.
64. J. M. Hammer, Pittsburgh, Pa.
65. Prof. A. Silverman, University of Pittsburgh, Pittsburgh, Pa.
66. J. O. Challinor, U.S. Glass Co., Pittsburgh, Pa.
67. C. E. Towers.
68. H. N. Clark.
69. T. C. Sutcliffe.
70. H. H. Asquith.
71. Duncan Webb, Jr.
72. A. L. Foster.
73. J. G. Bryce, U.S. Glass Co., Pittsburgh, Pa.
74. W. B. Mitchell.
75. J. W. Cruikshank, Pittsburgh, Pa.
76. Miss Cruikshank.
77. W. Butterworth, Jr.
78. Sven Fogelberg.
79. B. D. Varshnei.
80. J. L. Crawford, Mellon Institute, Pittsburgh, Pa.
81. W. Atack.
82. A. H. Stewart, Phœnix Glass Co., Monaca, Pa.

Attending the Banquet, but not included in the photograph:

H. W. Pai.
H. Gregg
J. G. Kaufmann, Pittsburgh, Pa.
R. F. Farmer, Pittsburgh, Pa.
George D. Willetts, Pittsburgh, Pa.

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OBITUARY NOTICE.

We regret to record the death of Mr. Richard Burtles at the age of sixty-nine. Mr. Burtles was a well-known figure in Manchester, both in the glass industry with which he had been connected for more than fifty years, and in the public life of that city. He was the second son of the late Thos. Burtles, the founder of Messrs. Burtles, Tate, Ltd., and in partnership with his elder brother, Thomas, controlled the business from 1875. His brother died in 1915.

In addition to an active business career, Mr. Burtles took part in the life of the city, being an Alderman on the City Council, on which he had served for eleven years, in addition to long service on the Levenshulme Urban District Council, of which he was at one time Chairman. Alderman Burtles was a member of the Gas Committee and of the Public Health Committee.

The funeral was attended by the Lord Mayor of Manchester, the Aldermen, and leading citizens, whilst deputations from various organisations with which he was connected were also present, Mr. Joseph Connolly representing the Society of Glass Technology.

TRANSACTIONS

LIST OF ABBREVIATIONS EMPLOYED IN THE JOURNAL.

Abbreviated Title.	Journal.
Amer. J. Sci.	American Journal of Science.
Analyst	The Analyst.
Ann. Physik	Annalen der Physik.
Ann. Physique	Annales de Physique.
Ber.	Berichte der Deutschen chemischen Gesellschaft.
Ber. Deut. physikal. Ges.	Berichte der Deutschen physikalischen Gesellschaft.
Bull. Soc. d'encouragement pour l'Ind. Nat.	Bulletin de la Société d'encouragement pour l'Industrie Nationale.
Chem. News	Chemical News.
Chem. Zeitung	Chemiker Zeitung.
Compt. rend.	Comptes rendus hebdomadaires des Séances de l'Académie des Sciences.
Deut. Mech. Zeitung	Deutsche Mechaniker-Zeitung.
Elektrotech. Zeitsch.	Elektrotechnische Zeitschrift.
Glashütte	Die Glashütte.
Glasindustrie	Die Glasindustrie.
J. Amer. Cer. Soc.	Journal of the American Ceramic Society.
J. Amer. Chem. Soc.	Journal of the American Chemical Society.
J. Ind. Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Physical Chem.	Journal of Physical Chemistry.
J. pr. Chem.	Journal für praktische Chemie.
J. Russ. Phys. Chem. Soc.	Journal of the Physical and Chemical Society of Russia.
J. Soc. Chem. Ind.	Journal of the Society of Chemical Industry.
J. Washington Acad. Sci.	Journal of the Washington Academy of Sciences.
Ker. Rundschau	Keramische Rundschau.
Mon. Scient.	Moniteur Scientifique.
Optician	The Optician and Scientific Instrument Maker.
Phil. Mag.	Philosophical Magazine.
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phys. Review	Physical Review.
Physikal. Zeitsch.	Physikalische Zeitschrift.
Proc. Inst. Chem.	Proceedings of the Institute of Chemistry.
Proc. Phys. Soc.	Proceedings of the Physical Society of London.
Proc. Roy. Soc.	Proceedings of the Royal Society.
Sprechsaal	Sprechsaal.
Tonind. Zeit.	Tonindustrie-Zeitung.
Trans. Amer. Cer. Soc.	Transactions of the American Ceramic Society.
Trans. Amer. Illum. Eng. Soc.	Transactions of the American Illuminating Engineers' Society.
Trans. Cer. Soc.	Transactions of the Ceramic Society.
Trans. Farad. Soc.	Transactions of the Faraday Society.
Trans. Optical Soc.	Transactions of the Optical Society.
Zeitsch. analyt. Chem.	Zeitschrift für analytische Chemie.
Zeitsch. angew. Chem.	Zeitschrift für angewandte Chemie.
Zeitsch. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitsch. Elektrochem.	Zeitschrift für Elektrochemie.
Zeitsch. Instrumentenkunde	Zeitschrift für Instrumentenkunde.
Zeitsch. physikal. Chem.	Zeitschrift für physikalische Chemie, Stöchiometrie und Verwandtschaftslehre.

S K . . . . Seger Cone.

All temperatures are expressed on the Centigrade scale.

The abstracts of patents are taken by kind permission of the Controller, H.M. Stationery Office.

I.—*The Development of Various Types of Glass. Part I. The Interaction of Silica with the Oxides of Sodium and Potassium.*

By C. J. Peddle, M.Sc.

Introduction.

During the past four years the author has been engaged on the production of optical glass, and has studied glasses of many varying types. A considerable amount of knowledge has accumulated from this study, and glass technologists may be interested to have some of the information at their disposal.

The manufacture of optical glass is perhaps the most exacting of all the branches of the glass industry, seeing that the optician demands a very high standard in the quality of the glass for his prisms and lenses. In optical glass production the following points have all to be taken into account:—

(1) Each glass must have certain refractive indices for various wave-lengths of light, and successive melts of the same type of glass must only vary within narrow limits in their respective indices.

(2) The glass must be as free from bubble as possible.

(3) No veins must be present. Absence of veins or striæ, visible to the naked eye alone, is not sufficient, and glass has to be examined on a special instrument for the presence of "fine striæ."

(4) Even in pieces one to two inches thick there must be practically no colour. In addition, freedom from colour must be brought about without the use of "decolorisers," such as manganese dioxide, nickel oxide, or selenium, because the glass must transmit a maximum of light.

(5) It is essential that the glass shall be very durable, that is, it must preserve its polished surface undimmed and without disintegration after long usage under all climatic conditions.

(6) The glass must be free from strain, and so demands a high

degree of annealing, a particularly delicate operation with thick pieces of glass.

(7) The working properties of the glass must be such that it can be easily fashioned into lenses and prisms. It must not be too hard nor too brittle, so that it may be ground and polished.

(8) The batch mixture must be such as to admit of easy founding under normal glass melting conditions, and yield a glass of sufficiently low viscosity when molten as to admit of easy stirring.

(9) After stirring, the pot of optical glass is allowed to cool down *in situ*, and is broken up when cold. This cooling must be at a fairly slow rate (a matter of days), so that fairly large pieces of glass are available. Slow cooling introduces another pitfall into the operation, namely, the separation from the glass of one or more of its constituents, leading to "devitrification." * Thus care has to be exercised that composition and rate of cooling are such that no separation takes place.

Consideration of the above points makes it obvious that no successful attempt could be made to manufacture optical glass unless a considerable amount of research were carried out dealing with each point mentioned. The papers which follow deal with this research. In the early days of the development of different optical glasses by the author, recourse was had to the analysis of existing types, chiefly made by Schott at Jena. This method has severe limitations, and was soon abandoned. In the first place, batches worked out from analysis, even allowing for volatilisation, did not yield a glass of the required optical constants. Secondly, the method is the crude one of the copyist, and does not make for the production of new types of glass on which advance in optical instruments depends, nor for the improvement of old types. Instead of using analysis, a study of the influence of various glass-making oxides on one another was substituted, beginning with the simplest glasses and leading up to the more complex. So successful has this method been that, within three years, more than seventy different glasses have been developed and are being regularly reproduced by the author's firm from formulæ built up in this way. Some of these glasses are quite new, whilst others are reproductions of types already in use, although in many cases none of the type glass was available for experiment.

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* In the literature of glass it is not always clearly conveyed what is meant by "devitrification." In its widest sense it means the separation from glass of any constituent in any form, crystalline or amorphous. Some writers would distinguish it from "opalisation," only regarding visible aggregates either crystalline or amorphous as "devitrification." Again, it is used only in the sense of "crystallisation" by others—thus where cloudiness in glass is due to minute crystallisation such opalisation would be regarded as "devitrification."

Separations from glass may be divided into four classes.

(1) Separation of crystalline particles large enough to be easily distinguished, the glass having no milky or cloudy appearance.

(2) Separation of particles as in (1), but non-crystalline.

(3) Separation of crystalline particles, but so small as to give the glass a milky or opal effect.

(4) Separation of non-crystalline particles with accompanying opal effect.

The author would narrow the meaning of the term "devitrification" to the first two classes, distinguishing them as "crystalline" and "amorphous devitrification" respectively. Classes (3) and (4) would be regarded as "opalisation" and termed "crystalline" and "amorphous opalisation" respectively. It must be borne in mind that both "devitrification" and "opalisation" imply that there has been total solution at one period of the existence of the glass followed by separation. Certain opal glasses are not examples of true "opalisation" because when gathered at founding temperature they are not clear, being suspensions and not solutions.

The normal glass may be regarded as the result of the interaction of various chemical compounds to form new compounds which at the high temperature of formation are mutually soluble and remain so when cold. An intimate knowledge of glass production may be obtained by the study of the influence of any one particular radicle on the various properties of glass, such as refractive index, colour, durability, density, hardness, melting point, viscosity, expansion, and corrosive action when molten on pot clay, etc.

I. The Interaction of Silica and Sodium Oxide.

The simplest normal glass that can be formed is one consisting of two radicles, one basic and one acidic, and glasses of this type can be made by melting together silica and an alkali oxide, such as oxide of sodium or oxide of potassium. Melts were carried out using different proportions of silica and sodium oxide molecules, according to the scheme in table I. In the same table the batch compositions are shown worked out in terms of the oxide percentages. The silica was introduced in the form of Fontainebleau sand and the sodium oxide in the form of sodium carbonate. All the substances used in the researches which follow were ordinary glass-making materials precisely the same as those used for large melts in the works, so that the results obtained might be correlated to works practice. These batch substances, although the purest obtainable, contained slight impurities which were known from analysis, so that exact batch composition was known in each case.

TABLE I.

Melt No.	Proportion of silica molecules.	Proportion of sodium oxide molecules.	SiO_2. Per cent.	Na_2O. Per cent.	Al_2O_3 and Fe_2O_3. Per cent.
162 *A*	100	20	83·00	16·58	0·42
B	100	30	76·64	22·98	0·38
C	100	40	71·20	28·44	0·36
D	100	50	66·46	33·21	0·33
E	100	60	62·32	37·37	0·31
F	100	70	58·68	41·03	0·29
G	100	80	55·42	44·30	0·28
H	100	90	52·52	47·22	0·26
K	100	100	49·91	49·84	0·25

In all the researches carried out by the author, molecular proportions were used as a basis, the proportion of SiO_2 molecules being taken as 100, for the sake of convenience. When the molecular basis is used there is only one variant oxide, the rest remaining constant at discretion. At least two oxides must be variable when the basis of percentage composition is used.

No nitrate or decoloriser was used in making up the batch, for it was hoped that the resultant glass colour might give some indication of pot attack.* The amount of each batch was about 200 grams,† and it was intimately mixed by grinding in a porcelain mortar. Each batch was melted in a special crucible ‡ under known conditions of time and temperature.§ The crucibles were provided with lids to eliminate as far as possible attack on the batch by hot furnace gases. The filling on period was one and a-half hours, and the melt was continued for three and a-half hours after the last filling. ‖ A few minutes before the end of the melt the molten glass was quickly stirred by means of a porcelain stirrer.

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* In all the melts this practice of using neither nitrate nor decoloriser was followed, and quite valuable results were obtained. The resultant colour was due to (1) the iron oxide in the batch, which was almost negligible, being only about 0·03 per cent., and so incapable of giving any observable colour to the small amount of glass produced ; (2) the iron oxide taken up from the pot by the attack of the molten metal. The depth of colour thus served to indicate severity of pot attack.

† Unless otherwise stated, in all the melts the batch mixture weighed about 200 grams and the whole of it was melted up.

‡ Throughout the work the crucibles used were of the same clay mixture as was used in making the large works pots. Before placing in the furnace they were raised to 900° in a small muffle.

§ Temperatures were read with a Cambridge optical pyrometer sighted through a hole in the furnace wall, the pyrometer being focussed on the pot. The furnaces were of the usual round Fletcher Russell type, and were heated by pressure burners using town's gas and air.

‖ As a rule the filling period lasted $1\frac{1}{2}$ hours, but the number of fillings varied, according to the "gassy" nature of the batch. Care was always taken to have no frothing out of the pot. The melt was run for $3\frac{1}{2}$ hours after the last filling to keep volatilisation conditions as equal as possible for each melt.

Results.

Series 162.

1. Number of fillings = three at half-hour intervals.
2. Time of founding = three and a-half hours after last filling.
3. Temperature = 1350° for last three hours.
4. The batches fluxed as their Na_2O content increased, but at 1350° even those richest in SiO_2 gave glass. The viscosity decreased as the Na_2O increased.
5. The melts were allowed to cool down in the furnace and on breaking up the following points were noted:—

TABLE II.

No.	Mols. SiO_2.	Mols. Na_2O.	Remarks.
162 *A*	100	20	Very hard glass, slightly milky. White scum on surface. SiO_2 separations in body of melt.
B	100	30	Light blue-green. No bubble nor scum.
C	100	40	Green glass. Quite plain.
D	100	50	Yellow glass. Do.
E	100	60	Light blue-green. Do.
F	100	70	Light blue. Do.
G	100	80	Blue. Do.
H	100	90	Dark blue. Do.
K	100	100	Dark yellow-green. Do.

6. To test the effect of temperature on fluxing, melts *A*, *B*, *C*, *E*, *G*, *K* were repeated at 1200°. At this temperature glass *A* ($100SiO_2, 20Na_2O$) did not flux, but remained a semi-porcelain-like mass, whilst glass *B* ($100SiO_2, 30Na_2O$) only became partly fluxed. The remainder all became fluxed with results similar to those obtained at 1350°, except glass *K* ($100SiO_2, 100Na_2O$). In this case devitrification took place, the top portion of the melt which cooled the quicker being a dark yellow glass, whilst the lower portion consisted of a mass of long, needle-like crystals, grey in colour.

The properties of the various glasses were then investigated in turn, beginning with density.

1. *Density.*

The usual method employed to find the density of glass is that of weighing in air and then in water, assuming the density value to be the same as that of the specific gravity so obtained. This method has been employed by the author in all the researches which follow, but in the case of the glasses under discussion it cannot be used owing to their extreme solubility in water.* They were therefore weighed in air and toluene, and their densities calculated accordingly. Table III shows the results obtained.

TABLE III.

Melt No.	Molecules.		Percentage.		Density.	Density calculated using Schott numbers.
	SiO_2.	Na_2O.	SiO_2.	Na_2O.		
162 *A*	100	20	83·00	16·58	2·353	2·355
B	100	30	76·64	22·98	2·413	2·372
C	100	40	71·20	28·44	2·457	2·387
D	100	50	66·46	33·21	2·495	2·400
E	100	60	62·32	37·37	2·521	2·411
F	100	70	58·68	41·03	2·535	2·422
G	100	80	55·42	44·30	2·544	2·431
H	100	90	52·52	47·22	2·555	2·439
K	100	100	49·91	49·84	2·560	2·446

Winkelmann and Schott † have analysed several glasses and calculated the density according to the formula

$$\frac{p}{d} + \frac{p_1}{d_1} + \frac{p_2}{d_2} \ldots\ldots = \frac{100}{D},$$

where D is the density of the glass, p, p_1, p_2, p_3 . . . are the percentages of constituent oxides, and d, d_1, d_2, d_3 . . . are the densities of the respective oxides. They point out that in order to bring the calculated values into line with the actual values the ordinary density values cannot be used. Instead, they assume that each oxide becomes denser when in glass, and they tabulate what they term "condensation" density values for each oxide. Thus they give the density of SiO_2 in glass as 2·3 (ordinary density = 2·17) and the density of Na_2O in glass as 2·6 (ordinary density = 2·55).

Using these values of Winkelmann and Schott the density values for 162 series have been calculated and are given in the last column of table III. It will be noted that there is considerable discrepancy between the calculated and the actual values.

The assumption that the density of glass can be calculated from the densities of the constituent oxides is in error, and the equation of Winkelmann and Schott for the calculation of density is of no use where "extreme" glasses are concerned, that is, glasses containing an abnormal amount of any constituent oxide.

The curves in Fig. 1 bear out this contention. Curve I shows

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* For solubility of these glasses see p. 14.

† *Ann. Phys.*, 1894, **51**, 741

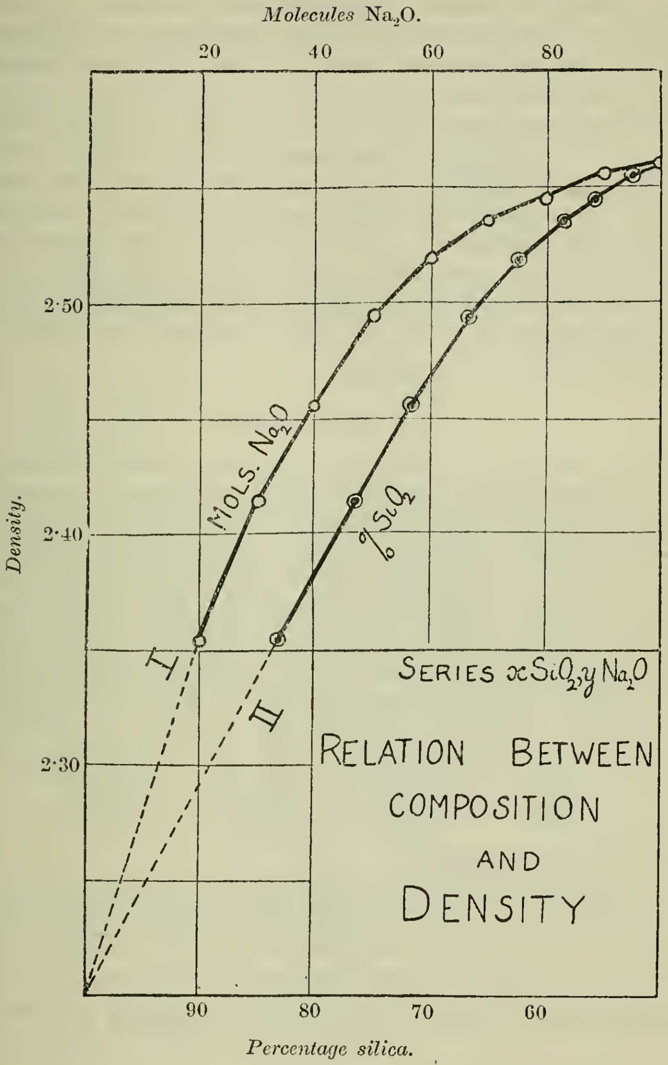

FIG. 1.

the variation of density with the increase in Na_2O molecules * (the silica molecules being taken as 100 in each case). Curve II shows

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* Owing to volatilisation during melting and to pot attack, the actual glass composition will be slightly different from that given by the batch. Work is proceeding on the analyses of these and other glasses, and sufficient knowledge is already available to show that the general conclusions to be

the variation of density with decreasing percentage of silica by weight. It will be noted that both lines are curved, the curve being particularly marked when it represents glasses containing extreme amounts of Na_2O.

The density of these glasses increases with increasing amounts of Na_2O. Thus the property of density is to some extent additive, but the relationship is by no means simple. Where large amounts of Na_2O are present, the additive nature is masked to some extent by constitutive properties. Curves I and II, when traced back to 100 molecules SiO_2, give as the density value of SiO_2 [illegible] 2·20.

It can also be shown by drawing a curve, keeping the Na_2O value constant and varying the SiO_2 value, that the density value for Na_2O is 2·625.

2. *Refractive Index.*

The property of refraction is of particular value in the designation of optical glasses, and the optical properties of a particular glass are always defined in terms of the refractive indices* for various lines of the spectrum. The four lines in most common use are: (1) the H_α (red) line of hydrogen; (2) the yellow sodium line; (3) the H_β (green) line of hydrogen; (4) the H_γ (purple) line of hydrogen. The first three are identical with the Fraunhofer lines *C*, *D*, *F* of the solar spectrum, whilst the fourth is near the *G* line. These four lines are usually denoted by the letters *C*, *D*, *F*, *G′*, and their wave-lengths are:

C (H_α line) red.	*D* (Na line) yellow.	*F* (H_β line) green.	*G′* (H_γ line) purple.
0·6563μ	0·5893μ	0·4862μ	0·4341μ

where $\mu = 0·001$ millimetre.

In specifying a glass for optical work, it is customary to give the refractive index for the *D* line only, together with the "total dispersion," the *difference* between the refractive indices of the *F* and *C* lines. Often the total dispersion is not given as such, but a value, known as the ν value, is used, and defined as $\nu = \frac{\eta_D - 1}{\eta_F - \eta_C}$, usually written as $\frac{D - 1}{F - C}$.

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drawn are in no wise altered by using batch compositions in place of actua composition. Owing to the long and tedious nature of glass analysis it is impossible to incorporate full results in this paper, and they are reserved for future publication.

* The most accurate method of finding the refractive index is by means of a good spectrometer. A quicker method, but not so accurate, is the Pulfrich refractometer.

For very accurate optical work, the dispersions between each pair of lines or the partial dispersions are required. Sometimes they are given as such, or they may be given in the form of a ratio with the total dispersion as denominator. For example,

$$\beta = \frac{\eta_F - \eta_D}{\eta_F - \eta_C} \quad \text{or} \quad \frac{F - D}{F - C},$$

$$\gamma = \frac{\eta_{G'} - \eta_F}{\eta_F - \eta_C} \quad \text{or} \quad \frac{G' - F}{F - C}.$$

Thus to properly specify a glass it is necessary to give the following four constants:—

(1) Refractive index for D line $= \eta_D$.
(2) ν value.
(3) β value.
(4) γ value.

Except in glass of the very best quality, it is impossible to get a reading on an instrument for the G' line. Thus with glasses made in the laboratory, it is only possible, as a rule, to obtain values for the C, D, F lines, as the glasses are almost invariably striated. In the values for refractive index which follow, the index for the D line and the total dispersion C to F are given as a general practice, together with the ν value. Where they are to be depended upon, the partial dispersions are given as well.

From each melt a cube with 1-inch edge was cut.* Two adjacent faces of this cube were ground flat and polished, and the cube was then used on a Pulfrich refractometer to find the refractive indices.

In the case of the first four glasses the lines were fairly good. In the later glasses the colour was too deep to allow easy visibility, and the lines could only be read with difficulty.

The following results were obtained †:—

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* In some melts it was impossible to obtain 1-inch cubes. When this was so, as large a polished surface as possible was used. No surface less than a ½-inch square was used in Pulfrich work.

† A second series gave :

SiO_2.	Na_2O.	Melt No.	
100	20	83 *A*	1·4852
100	30	*B*	1·4948
100	40	*C*	1·5024
100	60	*D*	1·5092
100	80	*E*	1·5137

The agreement between the series is very good for melts of this size.

TABLE IV.

Melt No.	Mols. SiO_2.	Mols. Na_2O.	η_D.	C to F dispersion $\times 10^5$.	ν.	Rise in η_D per molecule Na_2O $\times 10^5$.	Rise in dispersion per molecule Na_2O $\times 10^6$.
162 *A*	100	20	1·4851	790	61·4	—	—
B	100	30	1·4952	835	59·3	101	45
C	100	40	1·5015	875	57·3	63	40
D	100	50	1·5056	909	55·6	41	34
E	100	60	1·5090	937	54·3	34	28
F	100	70	1·5118	962	53·2	28	25
G	100	80	1·5139	983	52·3	21	23
H	100	90	1·5155	1002	51·5	16	19
K	100	100	1·5168	1017	50·8	13	15

These results serve to indicate that the refractive index and the dispersion both increase as the Na_2O content rises. Curve I on Fig. 2 shows the variation of refractive index with molecular composition. Curve II shows the variation of total dispersion, and curve III the variation of the ν value. The curves demonstrate admirably that the refractive index of these glasses cannot be expressed by simple additive relationships, but that constitutive properties come into play. The numbers in the two last columns also bear this out, the rise in refractive index per molecule Na_2O (SiO_2 being 100) decreasing as the Na_2O increases. The rate of decrease of η_D per molecule Na_2O is much greater than the rate of decrease of total dispersion.

A comparison of Fig. 2 with Fig. 1 shows that as the density of the glasses rises the refractive index also increases. Up to the composition $40Na_2O,100SiO_2$ the rate of increase is approximately the same, then the rate of increase of the density is greater than the rate of increase of refractive index, showing that the refractive index, although influenced by density, is affected by other factors.

A continuation of curve I to $SiO_2=100$, $Na_2O=0$ gives 1·4600 as the refractive index of silica with a total dispersion *C* to *F* of 0·00685 and a ν value of 67·1.

A curve may be drawn from the results, keeping the Na_2O value constant and varying the silica. This curve, of course, shows a decreasing refractive index as the SiO_2 increases, the rate of decrease becoming less with increase of SiO_2. The curve, on continuation, yields a value for the refractive index of sodium oxide = 1·5280. On plotting the total dispersion, it decreases with increasing silica content, and the rate of decrease falls rapidly as the silica content becomes greater. The curve gives the total dispersion *C* to *F* for Na_2O as 0·01165, and a ν value of 45·3.

3. *Devitrification.*

In cooling from 1350° to room temperature in twelve hours, that is, at a mean rate of 110° per hour, none of the melts showed any signs of separation except 162*A*. This contained a few white, segregated lumps of silica, each accompanied by a characteristic bubble, and the glass as a whole exhibited a blue milkiness. From this it may be deduced that any attempt to make this glass on a

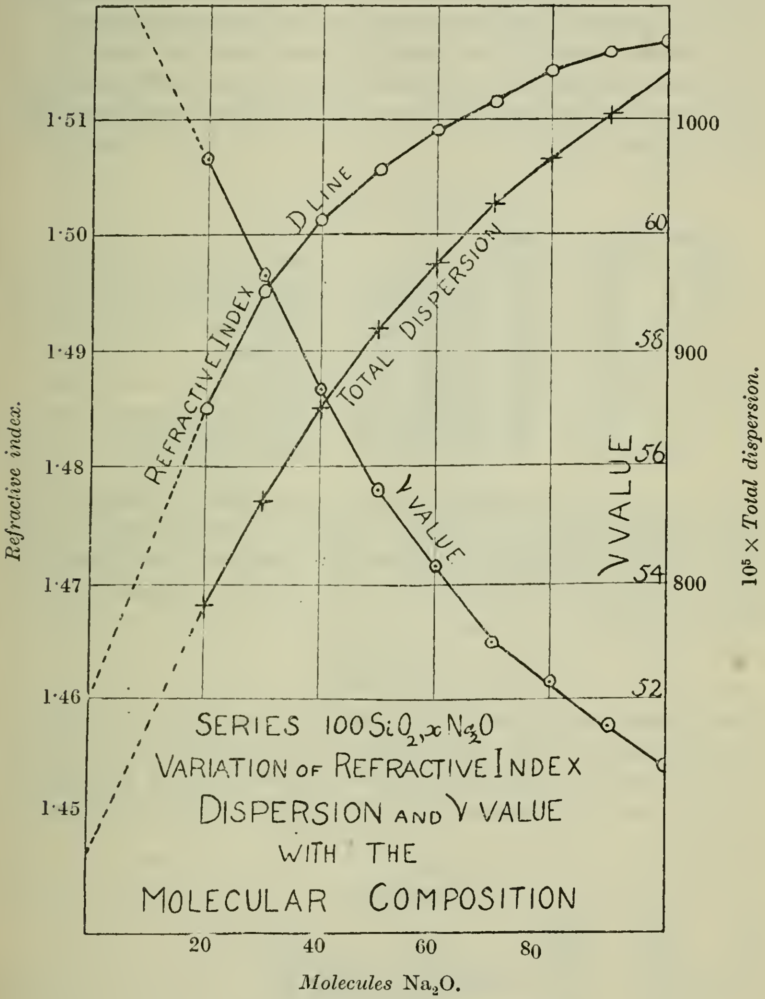

Fig. 2.

large scale, where the cooling extends over several days, would be attended by failure, as the melt would probably be quite opal.

A second series was cooled from 1100° to room temperature in twelve hours, when the glass $100Na_2O,100SiO_2$ devitrified, showing crystalline devitrification. The upper portion, which cooled fastest, remained glass, whilst the lower portion was entirely crystalline, being composed of long, needle-like, grey crystals.

An attempt was made to devitrify the glasses, as follows:—A small piece of each glass was heated slowly up to 900°, and kept at that temperature for six hours. It was then allowed to cool slowly to room temperature in twelve hours. The following results were obtained:—

TABLE V.

Melt No.	Mols. SiO_2.	Mols. Na_2O.		Result.
162 *A*	100	20	Did not melt.	Piece quite opal.
B	100	30	Did not melt.	Heavy semi-transparent scum.
C	100	40	Melted down.	Quite clear.
D	100	50	Melted down.	Quite clear.
E	100	60	Melted down.	Quite clear.
F	100	70	Melted down.	Quite clear.
G	100	80	Melted down.	White semi-porcelain mass.
H	100	90	Did not melt.	Porcelain-like mass.
K	100	100	Did not melt.	Porcelain-like mass.

These results prove that glasses between $40Na_2O,100SiO_2$ and $70Na_2O,100SiO_2$ (30 to 45 per cent. Na_2O) are difficult to devitrify. When the Na_2O content falls below 30 per cent., SiO_2 tends to separate out, and when it rises above 45 per cent., sodium silicates tend to separate.

4. *Solubility.*

Each glass was powdered and passed through a 160-hole sieve. Five grams of the dried powder were then digested with 100 c.c. of distilled water for one hour at 80°. The amount of undissolved material was then estimated by filtration, with the following results:—

TABLE VI.

Melt No.	Mols. SiO_2.	Mols. Na_2O.	Result.
162 *A*	100	20	68·08 per cent. insoluble.
B	100	30	25·29 per cent. insoluble.
C	100	40	Almost wholly soluble, there being a residue of from 0·4 to 0·6 per cent. in each case, probably an aluminium soda silicate, some alumina being present in the batch and some being taken up from the pot
D	100	50	
E	100	60	
F	100	70	
G	100	80	
H	100	90	
K	100	100	

On prolonged boiling, the glasses 162 *F*, *G*, *H*, *K* deposited a white, flocculent, gelatinous precipitate.* This increases with the amount of soda in the glass, and it is soluble in dilute HNO_3. In the case of 162 *F*, 3·23 per cent. of the original weight was deposited, and in the case of 162 *K* 18·72 per cent.

The fact that the two glasses 162 *A* and *B* are only partly soluble in water may be due to the fact that they are mixtures of soluble sodium silicates and silica in mutual solution, whilst the remaining glasses are composed wholly of mixtures of soluble sodium silicates, $x(Na_2O)y(SiO_2)$, and contain no free silica molecules.

5. *Durability, or Weathering.*

It is demanded of good optical glass that, after polishing, it shall keep its bright surface without tarnishing or disintegration over a long period. Different polished glass surfaces are affected in various ways. Some are covered with blotched, circular stains; others may become greasy. Again, glasses containing much barium or lead often become covered with iridescent-coloured patches. Some glass surfaces will scale, and become even entirely disintegrated. The effect upon a polished glass surface on exposure is termed "weathering."

The durability of a glass, or its weathering properties, can be tested in various ways. The best and only sure method is the actual effect on the glass lens or prism after exposure for a considerable time in an instrument under working conditions. Before a glass can be introduced into optical practice, tests which can be carried out quickly must be applied, and these tests may be many and various.† Exposure to steam under pressure, to acids and alkalis, to hot water, to various artificial atmospheric conditions, all find a place in testing, and the results obtained, as a rule, are parallel with those of the longer and surer method of actual use.

The glasses in this series were tested as follows:—

(1) By powdering and determining the solubility in water at 80°. This test has already been dealt with under "Solubility," and the results show that all the glasses are easily weathered, their durability decreasing with increasing Na_2O content.

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* On analysis after air-drying this precipitate was found to be composed of SiO_2 46·5, Al_2O_3 15·0, Na_2O 18·6, and H_2O 19·9 per cent., corresponding to a possible compound $Al_2O_3,2Na_2O,5SiO_2,7H_2O$.

† A discussion of the various tests of the durability of glass, together with a very full bibliography on the subject, will be found in this Journal, Trans. 1917, **1**, 160–161 ("The Attack of Chemical Reagents on Glass Surfaces and a Comparison of Different Types of Chemical Glassware," Cauwood, English, and Turner).

(2) The polished glasses were exposed to moist air for forty-eight hours and then examined.

(3) The polished glasses were exposed (*a*) for one week to ordinary atmospheric conditions; (*b*) for one year to ordinary atmospheric conditions.

The results of tests (2) and (3) are embodied in Table VII, and serve to bear out the results of the solubility tests.

TABLE VII.

Melt No.	Mols. SiO_2.	Mols. Na_2O.	Exposed 48 hours to moist air.	Exposed one week to ordinary air.	Exposed 12 months to ordinary air.
162 *A*	100	20	Quite unaltered	No effect visible	Very slight film.
B	100	30	,,	Very slight film	Slight film.
C	100	40	Slightly greasy	Greasy film	Thin, white film.
D	100	50	Quite greasy	Slight white film	,,
E	100	60	Very greasy	Distinct white film.	Thick white film.
F	100	70	Sticky	,, ,,	,, ,,
G	100	80	Very sticky	White film and crystals.	Thick corrugated film.
H	100	90	,,	White, more pronounced.	,, ,,
K	100	100	Hard crystals on surface.	White, very pronounced.	,, ,,

6. *Pot Attack.*

The fact that the glasses darken in colour with increase in the amount of Na_2O is an indication that pot attack increases as the Na_2O content rises, because this darkening is due to an increase in the iron oxide content of the glass. This iron oxide can only come from the pot.

It is also found on analysis that the alumina content of the glasses gradually increases as the percentage of Na_2O rises. This Al_2O_3 can only have been yielded by the clay of the pot.

Conclusions.

(1) Glasses of the type $100SiO_2,xNa_2O$ have been produced where x lies between 20 and 100, that is, Na_2O 17 and Na_2O 50 per cent.

(2) Glasses of the type containing more than 75 per cent. SiO_2 require temperatures greater than 1300° for their production.

(3) Glasses containing less than 70 per cent. SiO_2 all melt down at temperatures below 900°.

(4) When the Na_2O content of the soda–silica glasses exceeds 28 per cent., the glass is totally soluble in water. This indicates that no free silica molecules are present in the glass.

(5) There is increased pot attack with increasing Na_2O content.

(6) Glasses containing between 28 and 40 per cent. Na_2O are not subject to devitrification. Below 28 per cent. Na_2O, the

separation of SiO_2 can be induced. Above 40 per cent. Na_2O, crystallisation of sodium silicates can easily be brought about.

(7) When the Na_2O content is greater than 20 per cent., the glasses weather rapidly, the order of weathering, solubility, and Na_2O content being the same.

(8) The densities increase with increasing Na_2O content, but the rate of increase falls rapidly above 40 per cent. Na_2O. The density of silica is shown to be 2·220 and Na_2O 2·625.

(9) The refractive indices for the *C*, *D*, *F* lines have been found. They increase with increasing Na_2O, but rate of increase falls more rapidly than in the case of density.

(10) Both density and refractive index are properties additive in character, but they are also, particularly in later glasses of the series, constitutive.

(11) The values for the chief optical constants of SiO_2 in these glasses are shown to be:—

$$\eta_D = 1{\cdot}4600,$$
$$\text{Dispersion } C \text{ to } F = 0{\cdot}00685,$$
$$\nu = 67{\cdot}1.$$

(12) The corresponding values for Na_2O are:—

$$\eta_D = 1{\cdot}5280,$$
$$\text{Dispersion } C \text{ to } F = 0{\cdot}01165,$$
$$\nu = 45{\cdot}3$$

(13) None of the glasses would be of use for optical work. All except the first of the series are of very low durability, and the first glass becomes easily devitrified.

II.—THE INTERACTION OF SILICA AND POTASSIUM OXIDE.

The melting scheme in molecules and the percentage oxide composition of the batches is shown in Table VIII below. Fontainebleau sand and potassium carbonate were used in making up the batches. The potassium carbonate was a very good sample, being free from chlorides, sulphates, and phosphates. It contained about 10 per cent. moisture, which was allowed for in making up the batches.

TABLE VIII.

			Percentages.		
No.	Molecules SiO_2.	Molecules K_2O.	SiO_2.	K_2O.	$Al_2O_3+Fe_2O_3$.
84 *A*	100	20	76·00	23·60	0·40
B	100	30	67·94	31·72	0·34
C	100	40	61·27	38·44	0·29
D	100	60	51·44	48·31	0·25
E	100	80	44·24	55·54	0·22
F	100	100	38·84	60·96	0·20

Results.

(1) Considerable difficulty was experienced with these melts, as the batches were extremely "gassy" and boiled over continually. No large pieces were obtainable. At first it was intended to try to obtain larger pieces by melting together sand and a potassium silicate of known composition, in the hope that the boiling over might be eliminated. The extremely poor durability of these glasses did not make it worth while attempting a further series of melts.

(2) All the glasses were practically colourless, and all were totally soluble in water except 84 *A*, which did not all dissolve.

(3) There were no signs of devitrification, nor did a second heating and slow cooling induce any.

(4) All the glasses were very low in durability. Thus, $100SiO_2,100K_2O$ and $100SiO_2,80K_2O$ became mere pools of sticky liquid on standing for twenty-four hours. The glasses $100SiO_2,60K_2O$, and $100SiO_2,40K_2O$ became liquid after a few days. The glass $100SiO_2,30K_2O$, after keeping several weeks, was transformed into an egg-shaped, gum-like mass.

(5) Owing to the small pieces and the extreme solubility of the glasses, no densities or refractive indices could be found by the direct method.

(6) The densities of two of the glasses were found by extrapolation from two later series of lime–potash–silicate glasses (see Part III, p. 49).

Thus, for $100SiO_2,20K_2O$ the density is 2·388 ($100SiO_2,20Na_2O$ = 2·353), and for $100SiO_2,40K_2O$ the density is 2·465 ($100SiO_2,40Na_2O$ = 2·457).

(7) The refractive indices of the same two glasses were also found by extrapolation from the two series $100SiO_2,20K_2O,xCaO$ and $100SiO_2,40K_2O,xCaO$ (Part III, p. 54). The results were as under, the corresponding silica–soda glass being placed alongside for comparison:—

Glass.	η_D.	*F – C.*	ν.
$100SiO_2,20K_2O$	1·4937	0·00809	61·2
$100SiO_2,20Na_2O$	1·4851	0·00790	61·4
$100SiO_2,40K_2O$	1·5073	0·00888	57·1
$100SiO_2,40Na_2O$	1·5015	0·00875	57·3

It will be noted that in both cases the potash glass has a higher refractive index and a higher total dispersion than its corresponding soda glass.

Conclusions.

(1) Glasses of the type $100SiO_2,xK_2O$ are difficult to produce and cannot be preserved except in a dry, CO_2-free atmosphere.

(2) The durability decreases and the solubility increases as the K_2O content rises. Glasses of this type containing more than 30 per cent. K_2O are totally soluble in water.

(3) Compared with glasses containing Na_2O, substituted molecularly for K_2O, the following points are to be noted:—

(*a*) The potash glasses are easier to melt.

(*b*) The potash glasses exhibit less colour and are less durable.

(*c*) The potash glasses between 20 molecules and 40 molecules have a higher η_D and a higher total dispersion. This may be true for the whole series, but no data are available.

III.—THE INTERACTION OF SILICA AND THE OXIDES OF SODIUM AND POTASSIUM.

A scheme of melts was carried out, using molecular proportions as under.

TABLE IX.

Melt No.	Molecules SiO_2.	Molecules Na_2O.	Molecules K_2O.
85 *A*	100	10	10
B	100	15	15
C	100	20	20
D	100	30	30
E	100	40	40
F	100	50	50

In melting, the glasses behaved like the K_2O series, and so only small pieces were obtainable. The properties of the glasses, as far as could be judged, were intermediate between those of the Na_2O series and the K_2O series. No direct measurements of density or refractive index were obtainable, but for two of the glasses ($100SiO_2,10Na_2O,10K_2O$ and $100SiO_2,20Na_2O,20K_2O$) values for density and refractive index were obtained by extrapolation (see Part IV, pp. 62 and 66).

The densities of these two glasses were as follows, the corresponding Na_2O and K_2O glasses being also given for comparison. In the same table the values for refractive index are given.

Glass.	Density.	Refractive index for *D* line.	Total dispersion.	ν.
$100SiO_2,20Na_2O$	2·353	1·4851	0·00790	61·4
$100SiO_2,10Na_2O,10K_2O$	2·377	1·4892	0·00803	60·9
$100SiO_2,20K_2O$	2·388	1·4937	0·00809	61·2
$100SiO_2,40Na_2O$	2·457	1·5015	0·00875	57·3
$100SiO_2,20Na_2O,20K_2O$	2·472	1·5044	0·00882	57·15
$100SiO_2,40K_2O$	2·465	1·5073	0·00888	57·1

Conclusions.—The glasses of the series $100SiO_2,xK_2O,xNa_2O$ are intermediate in their properties between those of the series $100SiO_2,xK_2O$ and $100SiO_2,xNa_2O$. The refractive indices show this extremely well.

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II.—*The Development of Various Types of Glass. Part II. The Interaction of Silica, Lime and Sodium Oxide.*

By C. J. PEDDLE, M.Sc.

THE majority of the commercial glasses in use at the present time are manufactured by the interaction of silica and the oxides of sodium and calcium at high temperatures. The fact that lime confers special properties of durability upon glass containing it has been known from the early days of glass manufacture. It was natural, therefore, to make the investigation of the influence of calcium oxide upon the oxide of sodium and silica the next step in the development of types of glass.

Two series of melts were carried out according to the scheme outlined below (Table I), the numbers indicating molecules in each case. The basis or nucleus of the first series is the glass $100SiO_2,40Na_2O$ (that is, glass 162 *C*; see Part I, this JOURNAL, Trans., p. 8). The "nucleus" of the second series is the glass $100SiO_2,20Na_2O$ (that is, glass 162 *A*; see Part I, *ibid.*).

TABLE I.

Series $100SiO_2,40Na_2O,xCaO$.				Series $100SiO_2,20Na_2O,xCaO$.			
Melt No.	Molecules. SiO_2.	Molecules. Na_2O.	Molecules. CaO.	Melt No.	Molecules. SiO_2.	Molecules. Na_2O.	Molecules. CaO.
163 *A*	100	40	5	165 *A*	100	20	5
B	do.	do.	10	*B*	do.	do.	10
C	do.	do.	15	*C*	do.	do.	15
D	do.	do.	20	*D*	do.	do.	20
E	do.	do.	30	*E*	do.	do.	30
F	do.	do.	40	*F*	do.	do.	40

There is only one variant oxide in each series, namely, CaO, the "nucleus" of each glass in a series being the same, and this "nucleus" is the molecular SiO_2 and Na_2O content.

In making up the batches, the Na_2O was supplied by sodium carbonate, the silica by Fontainebleau sand, and the CaO by calcium carbonate. Ordinary materials as used in large optical melts were employed, the $CaCO_3$ being a very pure, precipitated chalk. No nitrate or decoloriser was used.

The batch compositions, expressed in terms of percentage oxides, were as follows:—

TABLE II.

Series $100SiO_2,40Na_2O,xCaO$.					Series $100SiO_2,20Na_2O,xCaO$.				
Melt No.	Per cent. SiO_2.	Per cent. Na_2O.	Per cent. CaO.	Per cent. $Al_2O_3 + Fe_2O_3$.	Melt No.	Per cent. SiO_2.	Per cent. Na_2O.	Per cent. CaO.	Per cent. $Al_2O_3 + Fe_2O_3$.
163 *A*	68·91	27·54	3·22	0·33	165 *A*	79·90	15·97	3·73	0·40
B	66·76	26·68	6·23	0·33	*B*	77·03	15·39	7·19	0·39
C	64·74	25·87	9·07	0·32	*C*	74·37	14·85	10·41	0·37
D	62·84	25·12	11·73	0·31	*D*	71·86	14·36	13·42	0·36
E	59·36	23·72	16·62	0·30	*E*	67·36	13·44	18·86	0·34
F	56·23	22·48	21·00	0·29	*F*	63·37	12·67	23·65	0·31

The melts were carried out as outlined in the previous paper

(1) Number of fillings = Three, at half-hour intervals.
(2) Time of founding = 3½ hours after last filling.
(3) Temperature = 1350° for the last three hours.

Results.

(1) The following points were noted after cooling down in the furnace.

TABLE III.

Series $100SiO_2,40Na_2O,xCaO$.		Series $100SiO_2,20Na_2O,xCaO$.	
Melt. No.	Remarks.	Melt No.	Remarks.
163 *A*	Almost colourless, Faint yellow.	165 *A*	Opalescent. White segregations in melt.
B	Almost colourless. Faint blue.	*B*	Light blue. White layer on surface.
C	Bluish-green.	*C*	Yellow. Slight white surface layer.
D	Yellowish-green.	*D*	Greenish-yellow.
E	Deep yellowish-green.	*E*	Yellow.
F	Muddy, dark yellowish-green.	*F*	Dark yellow. Devitrified at bottom.

(2) In both series the colour gradually deepened as the lime content increased.

(3) The colour was more pronounced in the series containing the higher sodium oxide content.

(4) The glasses in the second series were the more difficult to melt, proving the fluxing power of sodium oxide.

(5) The glasses containing the higher amount of sodium oxide were the more brittle.

THE PROPERTIES OF THE GLASSES.

1. *Density.*

The following were the density results found for the two series by the method of weighing in air and in water.

TABLE IV.

Series $100SiO_2,40Na_2O,xCaO$.				Series $100SiO_2,20Na_2O,xCaO$.			
Melt No.	Mols. CaO.	Per cent. CaO.	Density.	Melt No.	Mols. CaO.	Per cent. CaO.	Density.
163 *A*	5	3·22	2·503	165 *A*	5	3·73	2·412
B	10	6·23	2·533	*B*	10	7·19	2·458
C	15	9·07	2·559	*C*	15	10·41	2·499
D	20	11·73	2·584	*D*	20	13·42	2·537
E	30	16·62	2·629	*E*	30	18·86	2·603
F	40	21·00	2·667	*F*	40	23·65	2·659

The numbers above represent the mean of two sets of melts in each series, and a comparison of the two series is shown diagrammatically in Fig. 1.

The relationship between (1) percentage by weight of CaO and density is shown in Curves II and IV; (2) number of molecules of CaO and density is shown in Curves I and III.

The following conclusions are to be drawn from these results:—

(1) Density is greater in series containing greater Na_2O.

(2) Increasing the CaO content increases the density.

(3) Increasing the Na_2O content increases the density.

(4) The rate of increase of density is greater in the series containing lesser Na_2O. Thus the mean rise per molecule of CaO added in the $100SiO_2,40Na_2O$ series is 0·0049, and in the $100SiO_2,20Na_2O$ series is 0·0074. Therefore CaO has a greater effect on the density of a glass of this type the richer it is in SiO_2 and the poorer in Na_2O (see Table V).

(5) The increase in density per molecule of CaO added falls off in both series as the CaO content increases.

(6) The increase in density per 1 per cent. rise in CaO falls off in both series as the CaO content increases, but very slightly.

(7) Table V states the actual increases in each series for molecular addition and percentage addition, respectively, of CaO.

Table V.

Series $100SiO_2,40Na_2O,xCaO$.			Series $100SiO_2,20Na_2O,xCaO$.		
Mols. CaO.	Rise in density per mol. CaO($\times 10^4$).	Rise in density per 1 per cent. CaO($\times 10^4$).	Mols. CaO.	Rise in density per mol. CaO($\times 10^4$).	Rise in density per 1 per cent CaO($\times 10^4$).
5–10	60	99	5–10	92	133
10–15	52	92	10–15	82	127
15–20	50	94	15–20	76	126
20–30	45	92	20–30	66	121
30–40	38	87	30–40	56	117

It should be remarked that the increase of 1 per cent. CaO entails a fall of 1 per cent. in ($SiO_2 + Na_2O$).

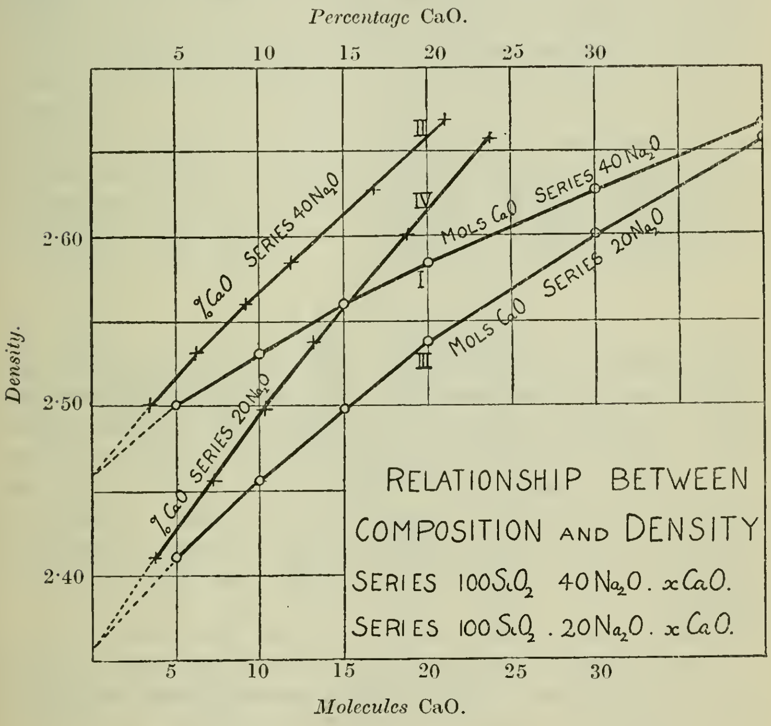

Fig. 1.

(8) It is evident that density is largely additive in its nature, but this additive relation is not a simple one, being modified according to the constitution of the glass, that is, it is also to some extent a constitutive property.

(9) If an attempt is made to calculate the density, using the

oxide composition of the glasses by the method proposed by Winkelmann and Schott (see Part I, p. 8), the values obtained differ considerably from the actual values, proving once more the limited value of this method.

(10) The values for the density of the two glasses

$100SiO_2,40Na_2O$

and $100SiO_2,20Na_2O$ are taken from the previous paper (*ibid.*, p. 8). It will be seen that these values lie very close to the extensions of the curves from the present series, and so serve to link up the two series.

(11) A comparison of the densities of the series $100SiO_2,xNa_2O$ (*ibid.*, p. 8) and the densities of the present series indicates that the rise in density, due to the molecular addition of CaO, is greater than that due to the molecular addition of Na_2O if these molecular additions are made to the same type of glass.

This ratio between the rise in density of a glass per molecule CaO added and the rise per molecule Na_2O added is not a constant one. It increases as the amount of Na_2O increases. For a glass of the type $100SiO_2,20Na_2O$, the addition of one molecule of CaO affects the density of the glass 1·8 times as much as the addition of one molecule of Na_2O. For the type $100SiO_2,40Na_2O$, the effect of CaO is 2·1 times that of Na_2O.

2. *Refractive Index.*

The glasses of both series were durable enough to get very satisfactory pieces cut and polished for work on the Pulfrich refractometer. During the grinding and polishing, the fact that increasing the Na_2O enhanced the brittleness was emphasised, whilst, contrary to expectation, in either series increasing the lime appeared to increase the toughness of the glass. It has been customary to regard high lime content as being conducive to brittleness, but it would appear that this view may have to be modified.

Readings were obtained on the Pulfrich refractometer for the C, D, and F lines of the spectrum, but it was not possible to read the G' line with any certainty, and in several glasses not at all. The results of the following measurements obtained are tabulated in Table VI *:—

(1) η_D; (2) $10^5 \times (F-C)$; (3) ν; (4) $10^5 \times (D-C)$, or the partial dispersion between the D and C lines multiplied by 10^5; (5) $10^5 \times (F-D)$, or the partial dispersion between the F and D lines multiplied by 10^5; (6) β.

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* Compare Part I, p. 10.

A knowledge of the β value, that is, the ratio of partial dispersion $F-D$ to total dispersion $F-C$, is of extreme importance in the computation of lenses, as it is not only necessary to know the total dispersion of a glass, but information must also be available as to the manner in which the glass divides up the spectrum. Thus, two glasses may have the same η_D value and the same total dispersion, but one may spread the blue end of the spectrum more than the other. It would thus have a higher β value. When the optical constants of a glass are supplied to the lens manufacturer, the β value is always included.

In addition to the β value, the further ratio $\left(\frac{\eta_F - \eta_{G'}}{\eta_F - \eta_C}\right)$, known as the γ value, is also supplied. Owing to the fact that glasses made on a small scale are seldom homogeneous enough to give the G' line of the spectrum on the refractometer with any clearness, it is impossible to include in the following table the γ values.

TABLE VI.

Melt No.	$x=$ mols. of CaO.	CaO. Per cent.	η_D*.	Total dispersion $10^5\times$ $(F-C)$.	ν.	Partial dispersion $10^5\times$ $(D-C)$.	Partial dispersion $10^5\times$ $(F-D)$.	β
			Type $100SiO_2,40Na_2O,xCaO$.					
163 *A*	5	3·22	1·5110	898	56·90	269	629	0·701
B	10	6·23	1·5189	918	56·53	274	644	0 702
C	15	9·07	1·5259	938	56·07	279	659	0·703
D	20	11·73	1·5327	955	55·78	283	672	0·704
E	30	16·62	1·5442	984	55·31	289	695	0·706
F	40	21·00	1·5540	1010	54·86	295	715	0·708
			Type $100SiO_2,20Na_2O,xCaO$.					
165 *A*	5	3·73	1·4970	815	61·98	245	570	0·700
B	10	7·19	1·5088	841	60·50	252	589	0·701
C	15	10·41	1·5192	865	60·03	258	607	0·702
D	20	13·42	1·5279	888	59·44	264	624	0·703
E	30	18·86	1·5435	934	58·20	276	658	0·705
F	40	23·65	1·5573	980	56·87	287	693	0·707

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* A second series gave for η_D:—

163 Type	$A=1·5107$	165 Type	$A=1·4975$
	$B=1·5184$		$B=1·5088$
	$C=1·5259$		$C=1·5196$
	$D=1·5323$		$D=1·5276$
	$E=1·5447$		$E=1·5436$
	$F=1·5555$		$F=1·5582$.

A comparison of the two series is shown diagrammatically in Fig. 2. The following conclusions are to be drawn from Curves

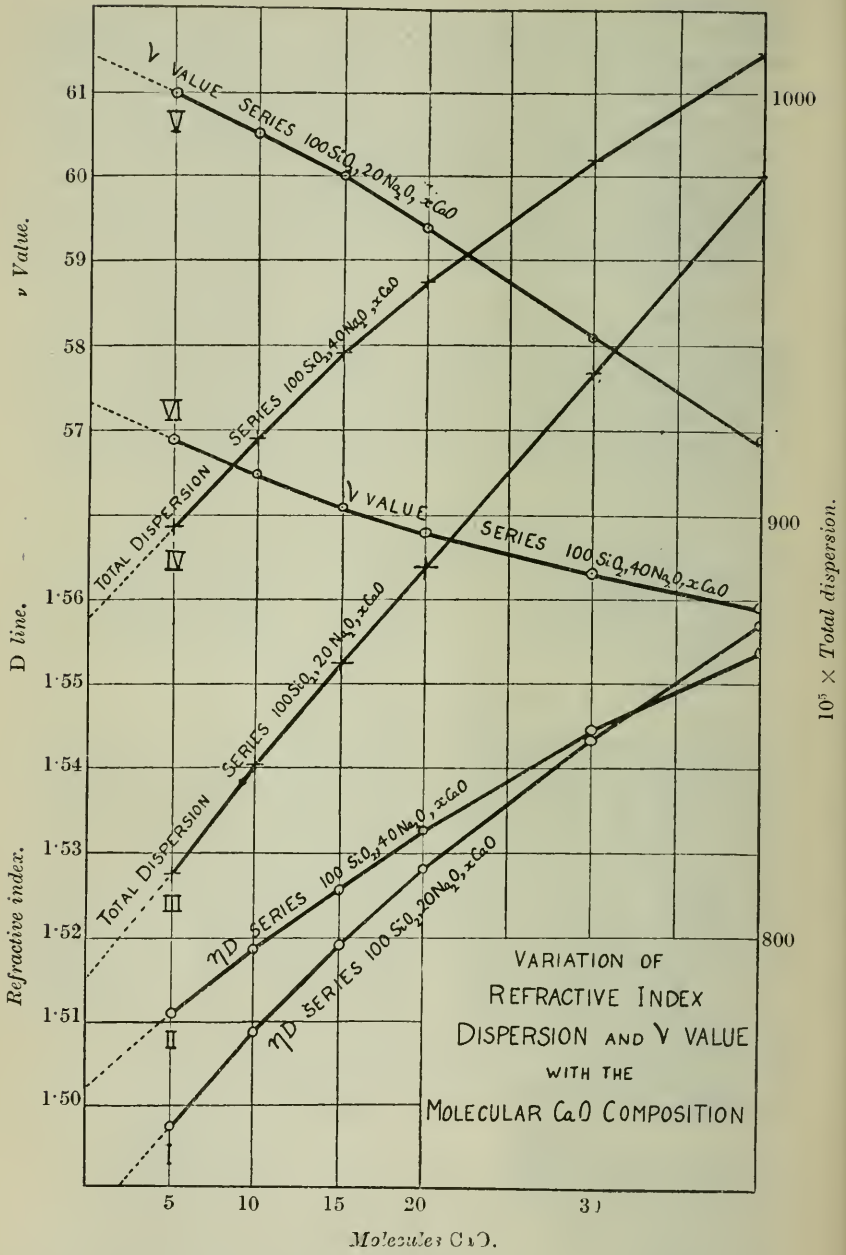
ν Value.
D line.
Refractive index.
10⁵ × Total dispersion.
Molecules CaO.
61
60
59
58
57
1·56
1·55
1·54
1·53
1·52
1·51
1·50
1000
900
800
5
10
15
20
30
ν VALUE SERIES 100SiO₂,20Na₂O,xCaO
ν VALUE SERIES 100SiO₂,40Na₂O,xCaO
TOTAL DISPERSION SERIES 100SiO₂,40Na₂O,xCaO
TOTAL DISPERSION SERIES 100SiO₂,20Na₂O,xCaO
ηD SERIES 100SiO₂,40Na₂O,xCaO
ηD SERIES 100SiO₂,20Na₂O,xCaO
I
II
III
IV
V
VI
VARIATION OF REFRACTIVE INDEX DISPERSION AND ν VALUE WITH THE MOLECULAR CaO COMPOSITION

Fig. 2.

I and II, which represent variation in η_D in the two series with increased molecular CaO content:—

(1) The refractive index increases with increased molecular CaO content.

(2) The rate of increase falls as the molecular CaO content rises (see Table VII).

(3) The fall in the rate of increase of refractive index is greater in the series containing the greater amount of Na_2O (see Table VII).

(4) In the two series, where the molecular CaO content is the same, the glass containing the greater amount of Na_2O has the higher refractive index until a molecular content in the neighbourhood of 33 molecules of CaO is reached. Then the two glasses $100SiO_2,40Na_2O,33CaO$ and $100SiO_2,20Na_2O,33CaO$ have the same refractive index for the *D* line. (It should be noted that these two glasses have different refractive indices for the *C* and *F* lines respectively, that is, their total dispersions are different.)

(5) From these two series it can be said, in general, that in soda-lime–silicate glasses of the type $100SiO_2,xNa_2O,yCaO$, where x lies between 20 and 40 molecules and y between 0 and 40 molecules, the greater the amount of Na_2O in the glass the less will be the effect upon the refractive index of adding CaO. The converse is also true, seeing that the more CaO the glass contains the less is the effect upon refractive index of adding Na_2O. The above is possibly true for all values of x and y capable of yielding glasses, but it is a point for further investigation.

(6) Tables VII and VIII show the respective effects of CaO and Na_2O upon the refractive index for different concentrations of the two oxides. The increases in the index for the *D* line per molecule and per 1 per cent. by weight addition are shown side by side.

TABLE VII.

Rise in the Refractive Index of the D *Line due to the addition of* CaO.

Series $100SiO_2,40Na_2O,xCaO$.			Series $100SiO_2,20Na_2O,xCaO$.		
Mols. CaO.	$10^5 \times$ rise per mol. of CaO added.	$10^5 \times$ rise per 1 per cent. of CaO added.	Mols. CaO.	$10^5 \times$ rise per mol. of CaO added.	$10^5 \times$ rise per 1 per cent. of CaO added.
5—10	158	262	5—10	236	341
10—15	140	247	10—15	208	323
15—20	136	255	15—20	174	289
20—30	125	235	20—30	151	286
30—40	108	246	30—40	138	288

TABLE VIII.

Rise in the Refractive Index of the D *Line due to the addition of* Na_2O.

Molecules CaO in the glass.	$10^5 \times$ rise per molecule of Na_2O added.	$10^5 \times$ rise per 1 per cent. of Na_2O added.
5	70	121
10	51	89
15	33	61
20	24	45
30	14	7
40	−17	−33

From the above table it will be seen that when the glass contains more than 33 molecules of CaO, an addition of Na_2O decreases the index for the *D* line.

(7) Tables VII and VIII serve to show how far refractive index is additive in its nature. It will be observed that the additive relation is far from being a simple one, and that the constitution of the glass plays an important part in deciding the refractive index.

(8) These two tables also prove that the rate of fall in increase of refractive index is much greater in the case of Na_2O than in the case of CaO. Also the addition of a molecule of CaO has a much greater effect upon the refractive index of a glass of the $100SiO_2,xNa_2O,yCaO$ type than the addition of a molecule of Na_2O, even though the molecular weight of the latter is the greater. The ratio between the effect of CaO and the effect of Na_2O in any glass of this type is not a constant, but is always greater than unity, for example, in the glass $100SiO_2,20Na_2O,5CaO$ the effect of adding 1 molecule of CaO would be to raise the index for the *D* line 0·00250.* The effect of adding 1 molecule of Na_2O would be to raise it 0·00070, that is, a ratio value CaO to $Na_2O = 3{\cdot}57$. In the glass $100SiO_2,40Na_2O,10CaO$ the ratio value would be 2·92.

Curves III and IV in Fig. 2 show the variation of total dispersion in the two series with increase in molecules of CaO. The following remarks are to be made on total dispersion:—

(1) Where the molecular lime–silica contents are the same, the glass containing the highest number of Na_2O molecules has the highest dispersion.

(2) Total dispersion increases with increasing CaO.

(3) Rate of increase of total dispersion is greater in the series containing the smaller Na_2O content (see Table IX)

(4) This rate of increase tends to a constant value in the series

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* This value is got by extrapolation from the curve drawn up from values in Table VII, second series.

containing least Na_2O, but falls in the other series, as the CaO content increases (see Table IX).

(5) Table IX shows how the total dispersion in the two series is affected by the addition of (1) one molecule CaO, (2) 1 per cent. by weight CaO. Table X shows the effect of Na_2O on the dispersion.

TABLE IX.

Effect of CaO *on Dispersion.*

	Series $100SiO_2,40Na_2O,xCaO$.			Series $100SiO_2,20Na_2O,xCaO$.	
	10^6 × mean rise in total dispersion.			10^6 × mean rise in total dispersion.	
Mols. CaO.	Per mol. CaO.	Per 1 per cent. CaO.	Mols. CaO.	Per mol. CaO.	Per 1 per cent. CaO.
5—10	40	66	5—10	52	75
10—15	40	70	10—15	48	74
15—20	34	64	15—20	46	76
20—30	29	59	20—30	46	84
30—40	26	59	30—40	46	96

TABLE X.

The Effect on Dispersion of the addition of Na_2O.

Mols. CaO.	10^6 × rise in total dispersion per molecule of Na_2O added.	10^6 × rise in total dispersion per 1 per cent. of Na_2O added.
5	42	72
10	39	68
15	37	66
20	34	62
30	25	48
40	15	30

(6) Examination of Tables IX and X shows that the effect per molecule of CaO added decreases at a less rapid rate than the effect per molecule of Na_2O. Also in glasses of the type $100SiO_2,20Na_2O,xCaO$ the addition of CaO has a greater effect upon the dispersion than the addition of Na_2O.

(7) In general, from these results it can be said that total dispersion is additive in its nature, but the relation is not simple, constitutive influences also playing a part.

Curves V and VI in Fig. 2 show the ν values in the two series. These ν values are greater in the series containing the lesser Na_2O and decrease with increasing CaO content. It will be noted that in both series the ν values continually decrease as the refractive index for the D line increases.

A study of the partial dispersions $(\eta_D - \eta_C)$ and $(\eta_F - \eta_D)$ emphasises the following points:—

(1) Increasing the CaO in the glasses lengthens both the red end and the blue end of the spectrum in both series.

(2) The lengthening effect of CaO is greater in the series containing the lesser Na_2O. Thus between 5CaO and 40CaO in the series $100SiO_2,40Na_2O,x$CaO the partial dispersion D to F increases 0·00089. In the series $100SiO_2,20Na_2O,x$CaO the corresponding increase is 0·00123. Similarly, the partial dispersion C to D increases 0·00026 in the first series and 0·00042 in the second.

(3) The fact that the partial dispersions C to D and D to F both increase as the CaO content rises, that is, as the refractive index rises, proves that the addition of CaO affects the refractive index of the F line more than the refractive index of the D line, and the refractive index of the D line more than that of the C line. In other words, with increasing CaO the rate of increase falls more in the C line than in the D line and more in the D line than in the F line.

The β values, $\frac{\eta_F - \eta_D}{\eta_F - \eta_C}$, given in Table VI show that with increasing CaO the blue end of the spectrum is spread relatively more than the red, that is, the β value increases as the CaO content rises. Since, as previously pointed out, this β value is of prime importance in the computation of lens systems, it has to be taken into account in devising optical glass batches. Their composition has to be such that not only will the resulting glass have a certain refractive index and a certain total dispersion, but this total dispersion must be spread over a particular portion of the spectrum, so that the blue portion bears a definite relation to the red.

A comparison of the β values in the two series shows that the relative spread is greater in the series containing the greater amount of sodium oxide. Thus, increasing the Na_2O in a batch of this type not only increases the total dispersion, but also increases the blue end of the spectrum relative to the red.

The Calculation of Batches for Optical Glasses.

From the results set out above, a great number of batch formulæ for glasses can be devised, and it may be of interest at this stage to show how a batch formula for a given glass can be calculated.

Suppose two glasses were required for lenses, both having a refractive index for the D line of 1·5150, the ν value of one to be 60·2 and the other 58·9. A batch mixture for each glass would be computed as follows:—

No. 1.—Required $\eta_D = 1{\cdot}5150$. $\nu = 60{\cdot}2$. Total dispersion $(F - C) = \frac{\eta_D - 1}{\nu} = 0{\cdot}00855$.

From the previous results we have the following facts:—

(1) Glass $100SiO_2, 20Na_2O, 10CaO$ has $\eta_D = 1{\cdot}5088$. $F - C = 0{\cdot}00841$.

(2) Between 10 molecules of CaO and 15 molecules of CaO in this series, the addition of 1 molecule of CaO raises $\eta_D = 0{\cdot}00208$ and $F - C = 0{\cdot}000048$.

Thus, glass $100SiO_2, 20Na_2O, 13CaO$ will have $\eta_D = 1{\cdot}51504$.
$F - C = 0{\cdot}00855$.
$\nu = 60{\cdot}2$.

A batch for this glass would be (using about 200 grams):

$SiO_2 = 120{\cdot}6$ grams.
$Na_2CO_3 = 42{\cdot}4$ „
$CaCO_3 = 26{\cdot}0$

In order to test how far the above calculations were true, this batch was mixed and melted up under the usual conditions. The following results were obtained for the optical constants:

Melt 165 *G*.

$\eta_D = 1{\cdot}5154$.
$F - C = 0{\cdot}00856$.
$\nu = 60{\cdot}2$.

It will be seen that the numbers obtained by experiment correspond very closely with those predicted.

No. 2.—Required $\eta_D = 1{\cdot}5150$. $\nu = 58{\cdot}4$. Total dispersion $F - C = \frac{\eta_D - 1}{\nu} = 0{\cdot}00874$.

From previous results we have:—

(1) The glass $100SiO_2, 20Na_2O, 10CaO$ has $\eta_D = 1{\cdot}5088$. $F - C = 0{\cdot}00841$.

(2) Between 10 molecules of CaO and 15 molecules of CaO the addition of 1 molecule of CaO raises $\eta_D = 0{\cdot}00208$ and $F - C = 0{\cdot}000048$.

(3) At CaO 11·5 molecules, addition of 1 molecule of Na_2O raises $\eta_D = 0{\cdot}00045$ and $F - C = 0{\cdot}000038$.

Thus, glass $100SiO_2, 27Na_2O, 11{\cdot}5CaO$ will have $\eta_D = 1{\cdot}51507$.
$F - C = 0{\cdot}00875$.
$\nu = 58{\cdot}9$.

A batch for such a glass will be (for a 200 gram melt).

$SiO_2 = 120{\cdot}6$ grams.
$Na_2CO_3 = 57{\cdot}2$ „
$CaCO_3 = 23{\cdot}0$ „

Again, in order to test the calculation, the above batch was melted under the usual conditions, and the following results obtained:—

Melt 165 *H*.

$$\eta_D = 1·51527.$$
$$F - C = 0·00875.$$
$$\nu = 58·9.$$

Once more it will be seen that the actual experimental result is very close to the predicted one, proving the efficacy of this method of working out optical glass batches.

Modifications Required for Large-scale Meltings.

It should be noted in passing that these batches will give the glasses with the above refractive indices only on the scale of the melt from which the results were drawn (200-gram size) and under the same conditions of time and temperature. If the melts were carried out on a large works scale, say, in pots holding 10 cwt. of glass, then the above optical constants would not be obtained from these batches. This discrepancy in results is due to the difference in the conditions of the melt in each case. Size of melt and time of melting cause a difference in the amount of volatilisation that takes place, and also a difference in the amount of pot attack.

Pot attack and volatilisation are responsible, therefore, for the fact that with any given batch of this type the larger the melt the higher will be the refractive index of the final glass. Of the two causes pot attack is the chief. Pot attack is always more severe in a small pot than in a large pot made of the same clay material. This can be proved in various ways. Thus from the same batch, glass made in a large pot is always superior in colour to that made in a small pot, proving the absorption of less iron oxide from pot material. Again, on analysis the glass from the small pot always shows a higher percentage of alumina than that from the large pot, showing a greater absorption of pot material. Pot attack will be greater the greater the area in contact with unit weight of molten glass. Consider the case of two melts, one of 200 grams and the other of 10 cwt. In the smaller melt the pot will be about 2 inches in diameter and the metal 1 inch deep. The area attacked, therefore, by 200 grams of glass is 9·42 square inches. Thus unit weight subjects 0·046 square inch to attack in this small pot. To hold 10 cwt. of glass ([illegible]500,000 grams), a pot 36 inches in diameter and 10 inches deep is required. The area under attack will be about 2150 square inches. In this case only ~~0·00086~~ square inch is in contact with unit weight. In the
0 0043

two melt sizes considered, the area in contact with unit weight of molten glass is more than ~~fifty~~ 10 times as much in the small melt as in the large one, from which it follows that the greater pot attack will occur in the small melt.

Since the material absorbed from the pot is mainly silica, the glass from the small pot, exhibiting as it does the greater pot attack, will be richer in SiO_2 and poorer in CaO and Na_2O than that from the large melt. Now it has been proved that in the glasses of this type the one containing the more CaO or Na_2O has the higher index, and that the addition of silica lowers the index. Thus the glass from the larger melt, being richer in CaO and Na_2O and having had less SiO_2 added, will have the higher index.

The second factor playing a part in the alteration of index due to the size of the melt is volatilisation. In this type of glass the principal volatilising material is sodium oxide, the loss of which from the glass will result in a decrease of refractive index. There is always a difference between the percentage amount of Na_2O put into a batch and the amount in the glass made from it, but this percentage difference is very much the same, whatever the size of the melt. This would indicate that volatilisation is of the same order in both large and small melts, and so the index is not altered to different degrees in different sized melts owing to this volatilisation.

It should be borne in mind that volatilisation of Na_2O is not easily estimated, and that the difference in the percentage of Na_2O in the batch and in the final glass is not a true measure of it, owing to absorption from the pot of materials foreign to the batch. Thus, analysis of glass always yields a lower figure for the percentage Na_2O than would be the case if the glass were melted in a container unaffected by it, that is, the volatilisation number as given by the difference in analysis is too large.

Volatilisation of Na_2O depends upon several factors, the chief of which are temperature, time of founding, area of volatilising surface, mass of volatilising material, percentage of Na_2O in batch, type of glass, and pressure upon the surface of melt. It is therefore very difficult to estimate, just as it is difficult to find it by experiment, owing to the alteration of the composition of the glass by pot attack.

From the foregoing it will be seen that, before attempting a melt on the large scale, the above batches would have to be modified to yield the indices required, and the relationship between the indices of small and large melts is entailed. The question of these relationships has been worked out to some extent, but as the work is proceeding, this question cannot be discussed in the present paper.

Before leaving the discussion of refractive index, it should be pointed out that a continuation of Curves I and III gives values η_D 1·485, $F-C$ 0·00790, for the glass $100SiO_2,20Na_2O$. These values correspond exactly with those found by experiment for this glass.* Continuation of Curves II and IV gives values $\eta_D = 1{\cdot}502$ and $F-C = 0{\cdot}00877$ for the glass $100SiO_2,40Na_2O$. Experiment gave 1·5015 and 0·00875 (Part I, p. 12, Glass 162 *C*).

Comparing the refractive index with the density, it will be observed that as the one increases, so does the other in these glasses. In addition, the factors that bring about rise in refractive index also cause corresponding increase in the density. It is obvious, therefore, that in these glasses density and refractive index are closely related.

3. *Devitrification.*

(1) In cooling from 1350° to laboratory temperature in twelve hours, there were no signs of devitrification in series

$$100SiO_2,40Na_2O,xCaO.$$

(2) Under the same conditions, in the second series,

$$100SiO_2,20Na_2O,xCaO,$$

the glass with 5CaO was milky and contained white, segregated particles, indicating a separation of silica. The glass with 40CaO contained at the bottom, where the cooling had been slowest, spherical, white lumps. These lumps, on breaking, show the characteristic, well-known crystalline structure of the "dog" of bottle tanks, and were composed of calcium silicate.

(3) A second series of melts, cooled from 1100° to laboratory temperature in twelve hours, behaved precisely as above, the devitrification of the two glasses $100SiO_2,20Na_2O,5CaO$ and $100SiO_2,20Na_2O,40CaO$ being more pronounced.

(4) As a test of ease of devitrification, small pieces of each of the glasses were heated in a muffle to 900°, kept at that temperature for six hours, and then cooled to laboratory temperature in twelve hours. The following results were obtained.

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* See Part I, p. 12, Glass 162 *A*.

TABLE XI.

Melt No.	Mols. CaO $= x$.	CaO per cent.	Results.
			Series $100SiO_2,40Na_2O,xCaO$.
163 *A*	5	3·22	Melted. Quite clear. Slight transparent edge scum. No devitrification.
B	10	6·23	Melted. Quite clear. Less edge scum. No devitrification.
C	15	9·07	Melted. Quite clear. No edge scum. No devitrification.
D	20	11·73	Melted. Semi-porcelain mass. Devitrified.
E	30	16·62	Not melted. Semi-porcelain mass. Devitrified.
F	40	21·00	Not melted. White porcelain mass. Devitrified.
			Series $100SiO_2,20Na_2O,xCaO$.
165 *A*	5	3·73	Not melted. Heavy, white layer of devitrified silica.
B	10	7·19	Not melted. Heavy, white layer of devitrified silica.
C	15	10·41	Melted. Slight white layer, initial devitrification.
D	20	13·42	Melted. Quite clear. No scum. No devitrification.
E	30	18·86	Just melted. White porcelain mass. Crystalline devitrification.
F	40	23·65	Not melted. White porcelain mass. Crystalline devitrification.

(5) It will be seen from the above results that in Series I, as soon as the percentage of CaO reaches 11 to 12 per cent., the glasses of this type tend to devitrify on prolonged heating at 900°. Thus, increasing CaO in this series brings about devitrification.

(6) In the second series of glasses there is a tendency to a separation of SiO_2 as long as the percentage of SiO_2 is greater than 72 per cent. In this series, therefore, addition of CaO tends to prevent a devitrification of silica. Such a separation of silica is sometimes met with in actual manufacture. Thus, in the making of medical bottles from glass in pots, using a batch high in silica, separation of white particles in strings connected by striæ is sometimes to be found in the necks of the bottles. These white particles are composed mainly of silica. Owing to the continual use of cullet, the glass melted becomes richer in silica and poorer in sodium oxide than allowed by the batch formula, until, when the SiO_2 content reaches about 75 per cent., the glass deposits silica under favourable conditions. A preventive of this is the addition of either Na_2O or CaO, or both. If the melting properties of the glass allow it, it is better to add only CaO, so that the weathering properties do not suffer. From this it will

be seen that for a "safe" working glass of the lime-soda–silicate type, the percentage of SiO_2 in the final glass should not be allowed to rise above 72 per cent.

In this series, additions of large amounts of CaO bring about deposition of calcium silicate. It should be noted, however, that whereas in Series I a glass containing 11·7 per cent. CaO devitrifies under the conditions specified, in Series II as much as 13·4 per cent. did not bring about devitrification. It is evident, then, that devitrification is dependent, not only upon the amount of CaO in the glass, but also upon the relative amounts of SiO_2 and Na_2O, and that, viewed from the point of view of tendency to devitrify under the influence of CaO, the addition of SiO_2 tends to inhibit, and addition of Na_2O tends to encourage, separation. Thus it is quite possible that where excessive "dogging" is taking place in a tank furnace owing to excess of lime in the batch, the addition of alkali may serve to accentuate the condition, and the proper remedy is the addition of sand to the batch.

It should be remarked here that the question of devitrification of commercial batches is always influenced by the presence of alumina in them, as alumina is generally introduced in small quantities in some manner.

In all probability, the greater tendency for calcium silicate devitrification to take place in glass the richer it is in Na_2O is a question of viscosity. The glass with the higher SiO_2 will have the higher viscosity, and its tendency to "stiffen up" sooner will no doubt help to prevent the formation of devitrification nuclei.

4. *Solubility.*

Each glass was powdered and passed through a 160-hole sieve. Five grams of the dried powder were digested with 100 c.c. of distilled water for one hour at 80°. The amount of undissolved material was then estimated by filtration, and the amount of acid required to neutralise the filtrate was obtained by titration. The results were as under.

TABLE XII.

Series $100SiO_2,40Na_2O,xCaO$.				Series $100SiO_2,20Na_2O,xCaO$.			
	Milligrams per 100 grams.				Milligrams per 100 grams.		
Melt No.	Weight dissolved.	H_2SO_4 to neutralise.	Equivalent Na_2O.	Melt No.	Weight dissolved.	H_2SO_4 to neutralise.	Equivalent Na_2O.
163 *A*	24,854	18,445	11,670	165 *A*	2662	3028	1915
B	6724	8956	5664	*B*	1214	1337	845
C	2504	4261	2694	*C*	1186	663	419
D	1676	3734	2361	*D*	670	400	253
E	1296	2283	1444	*E*	530	343	217
F	474	1063	672	*F*	272	248	157

On comparing Tables II and XII, it will be seen that:—

(1) In both series the solubility falls as the CaO content increases. At first the fall is very rapid, but after 15 molecules of CaO (about 10 per cent.), the rate of decrease of solubility is much slower, particularly in Series II.

(2) Glasses of the first series are much more soluble than those of the second, that is, for equivalent molecular CaO content, the glass containing the least Na_2O is the least soluble.

(3) The weight dissolved was obtained by subtracting the weight of undissolved material from the weight of material at the beginning. The sulphuric acid required to neutralise the alkaline solution was found by experiment, and the "equivalent Na_2O" in the last column in each series was obtained from the H_2SO_4 figure, assuming the whole of the acid is taken up by Na_2O from the glass. In all probability the substance dissolved from the glass will be a sodium silicate, and thus the figures in the last column in each series will be too low to represent the true amount of glass dissolved. It will be noticed, however, that although too low, in Series I these figures are higher in the last four glasses than the amounts recorded under "weight dissolved." Thus the values in the "weight dissolved" column must be too low, which means that the weight of material undissolved as found by experiment is too high to represent the true weight of original glass not dissolved. It is evident, therefore, that some reaction has taken place between the glass and the water, possibly resulting in the formation of hydrated silicates.

In the second series, the Na_2O values are all less than the "weight dissolved" values, so that the latter may represent the true solubility of the glasses of this series. In view of the results in Series I, it is more likely that they represent the solubility less the weight of new compounds formed by the glass. Thus, how far heating a glass with water and weighing the insoluble portion represents the insolubility is very doubtful, owing to the chance there is of new insoluble compounds being formed.

For the purpose of comparison of solubility in these two series, the H_2SO_4 values are the most useful. They are also of the greatest value in comparing these series with similar series developed later.

(4) These results are a striking proof of the great value of CaO in rendering the glass containing it more insoluble, and therefore in all probability more durable. Decrease in solubility certainly depends upon addition of CaO, and so is additive in its nature. It is also largely affected by the other constituents present in the glass. Thus the glass $100SiO_2.20Na_2O.5CaO$

(165 *A*), containing only 3·73 per cent. CaO, is less soluble than $100SiO_2,40Na_2O,20CaO$ (163 *D*), which contains 11·73 per cent. CaO. This is due to the fact that the latter glass has in it 25·12 per cent. Na_2O and the former 15·97 per cent.

(5) In general, it can be said in glasses of the type $100SiO_2,xNa_2O,yCaO$, increasing the CaO decreases the solubility, whilst increasing the Na_2O increases the solubility. The results also indicate that increasing the SiO_2 lowers the solubility.

5. *Durability.*

(1) The solubility numbers given under the heading of "Milligrams H_2SO_4 per 100 grams" in Table XII give some indication of the relative durability of these glasses. Taking these numbers as criteria, the durability of the glasses increases with increasing CaO content, and contrasting the two series, the higher the Na_2O content the less durable is the glass.

As was stated in Part I (p. 15), the only real test of durability is the actual behaviour of the polished glass surface on prolonged usage in an optical instrument. It is a fact, however, that many of the laboratory tests for weathering, such as appearance of polished surface after treatment under various conditions, solubility of powdered glass, solubility of glass surface, etc., yield results which bear out the longer tests of actual use. In conjunction with the results gained by the opticians for glass under service conditions, these laboratory tests are of considerable value. The author has carried out a large number of experiments on optical glasses, both in actual use and in course of development, with a view to discover, first, how far the various laboratory tests are in line with one another and with the actual behaviour in everyday use,* and, secondly, which is the simplest and most expeditious laboratory test yielding results of value. For general purposes, the test of the solubility of the powdered glass as outlined on p. 36 has been proved best. All laboratory tests are open to objection, and this solubility test more so, perhaps, than some of the others, but in skilled hands it has yielded valuable results. How far it is in line with actually recorded results of behaviour on usage may be shown briefly, as follows.

In the well-known optical glass catalogue of the firm of Schott and Genossen, of Jena, the glasses are divided into five classes according to their durabilities, and tabulated under the headings h^1, h^2, h^3, h^4, h^5. The test applied was the extraction of alkali from freshly fractured surfaces after a seven days' exposure to an atmosphere saturated with moisture at 18°, using iodoeosin as an indicator. According to the amount of alkali extracted per square metre, the glass was placed under headings h^1, h^2, h^3, etc., the limits of durability in each case being:—

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* It is hoped that some of these results on durability will be published in the near future. It is impossible to refer to them at length in this paper.

$h^1 = 0—5$ milligrams of alkali extracted per sq. metre.
$h^2 = 5—10$,, ,, ,,
$h^3 = 10—20$,, ,, ,,
$h^4 = 20—40$,, ,, ,,
$h^5 =$ over 40 ,, ,, ,,

The Schott and Genossen firm therefore tabulated stability from the results of a laboratory test, and long usage of these glasses in optical instruments has proved that in the majority of cases the classification is correct. In the following table are given five Schott glasses, one from each of the above classifications. From actual usage, it is known that their behaviour from a weathering point of view is in the same order as the classification. The five glasses have been subjected by the author to the solubility test, and column 8 of the table states the results, expressed in milligrams of H_2SO_4, required to neutralise the filtrate after boiling per 100 grams of the powdered glass (test done upon 5 grams actually).

TABLE XIII.

Type* of glass.	Schott No.	Refractive index for *D* line.	Total dispersion *C* to *F*.	ν. value.	Order of weathering from actual usage.	Schott classification.	Mg. H_2SO_4 per 100 grams of glass.
L.B.F.	0·463	1·5646	0·01020	55·4	1	h^1	159
B.S.C.	0·144	1·5100	0·00797	64·0	2	h^2	362
S.C.	0·337	1·5144	0·00847	60·7	3	h^3	580
S.C.	0·203	1·5175	0·00877	59·0	4	h^4	729
S.C.	0·381	1·5262	0·01026	51·3	5	h^5	899

* L.B.F. = Light barium flint. B.S.C. = Borosilicate crown. S.C. = Silicate crown.

It will be seen that the solubility numbers follow the order given by both the actual glass behaviour and by the iodoeosin test.

Taking these solubility values as criteria, any glass to be useful in optical glass manufacture must have a H_2SO_4 value less than 1000 mg. per 100 grams, and to be really of first-class quality less than 200 mg. per 100 grams.

If the results for the glasses of the two series under consideration (Table XII, p. 36) are examined, it will be seen that none of the glasses in the series $100SiO_2,40Na_2O,xCaO$ come within the above category, and so all are ruled out as possible optical glasses on this account alone. In the second series, the last four glasses fall within the 1000-milligram limit, but none quite give the value for a first-class glass. Unfortunately, only one of these four glasses, 165 *D* ($100SiO_2,20Na_2O,20CaO$), does not exhibit devitrification tendencies (see p. 35), and thus from the point of view of actual manufacture only this glass, or glasses in its proximity, could be made for optical work. Its durability would probably be the equivalent of Schott's h^3.

A study of the percentage compositions (Table II, p. 21) in relation to the solubility values (Table XII, p. 36) shows that glasses of this type yielding H_2SO_4 values less than 1000 mg. all contain less than 15 per cent. of Na_2O. It would seem that the amount of Na_2O in these glasses plays the largest part in deciding their solubility in water and their weathering properties. Even the glass 165 *A*, although containing nearly 80 per cent. SiO_2, has a high solubility value (3028 mg.). Similarly, glass 163 *F*, although its CaO content is as high as 21 per cent., has a solubility value of 1063 mg.

In discussing these results, the fact that the presence of alumina in glass improves its durability must not be lost sight of. All the glasses in the two series contain alumina absorbed through pot attack, and therefore the results as set out are uniformly slightly too low. Since the amount of Al_2O_3 taken up is, as a general rule in these glasses, greater the greater the amount of Na_2O in the glass, the solubility of the glasses containing most Na_2O will be most influenced. Thus the presence of Al_2O_3 does not affect the *order* of solubility, and serves, in fact, to emphasise the remarks in the preceding paragraph.

(2) The durability test by exposure, as outlined previously,* yielded :—

TABLE XIV.

Melt No.	100 Hours' exposure to moist air at 18°.	Exposure of one year to ordinary atmospheric conditions.
	Series $100SiO_2,40Na_2O,xCaO$.	
163 *A*	Greasy film and drops of liquid.	Glass dull and covered with white, crystalline powder.
B	Slight greasy film.	Glass dull and signs of crystals.
C	Very slight greasy film.	Glass dull and signs of crystals.
D	Signs of being affected.	Glass dull and surface spotted.
E	Unaltered.	Glass dull and surface spotted.
F	Unaltered.	Surface dulled in patches.
	Series $100SiO_2,20Na_2O,xCaO$.	
165 *A*	Unaltered.	Surface dull in patches.
B	,,	Slight signs of filming.
C	,,	Unaltered.
D	,,	,,
E	,,	,,
F	,,	,,

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* Part I, p. 16

The results obtained from this second test bear out those of the solubility test. It is of interest to note that where the H_2SO_4 value is less than 3000 mg., the glass surface remains unaltered after 100 hours' exposure to moist air at 18°.

The greasy film on the glasses in Series I after the 100 hours' test is probably a solution of sodium hydroxide or sodium carbonate. Moisture in the air attacks the glass, extracting some of the Na_2O, and forms NaOH. This in process of time takes up carbon dioxide from the air and forms sodium carbonate. Thus the white, crystalline deposit on the glasses after continued exposure is sodium carbonate, probably containing water of crystallisation.

When these deposits or films are cleaned off the glass by washing with water and then by ethyl alcohol, the glass surface remains dull and is pitted, and presents iridescent patches when viewed by reflected light. Cubes of these glasses, which when freshly polished gave good lines on the Pulfrich refractometer, on cleaning, after long exposure, do not give lines at all. There is no doubt that the attack on these glasses goes well beneath the surface.

6. *Pot Attack.*

The fact that all the glasses prepared were coloured indicated pot attack, the colour being due to iron oxide absorbed from the dissolved pot clay. The batches contained, on an average, 0·02 per cent. of Fe_2O_3, an amount insufficient to yield perceptible colour in small pieces of glass.

In both series the colour deepened as the CaO content increased, but this deepening was not marked. The glasses of the series with the higher Na_2O content were much deeper in colour than their corresponding glasses in the second series.

The above facts were emphasised when the glasses were analysed and the alumina content obtained, as shown in Table XV.

TABLE XV.

Percentage Composition.

Glass.	Na_2O in batch.	CaO in batch.	$Al_2O_3+Fe_2O_3$ by analysis.	$Al_2O_3+Fe_2O_3$ absorbed.	Difference.
163 *B*	26·7	6·2	1·35	1·02	0·33
163 *F*	22·5	21·0	1·64	1·35	
165 *B*	15·4	7·2	0·75	0·36	0·24
165 *F*	12·7	23·7	0·83	0·52	

The original batches contained, on an average, 0·3 per cent. of Al_2O_3 (see Table II for actual amounts), so that the extra Al_2O_3 must have been absorbed by the molten glass from the pot.

It will be seen that increasing the CaO content from 5 molecules to 40 molecules results in an absorption difference of 0·33 per cent. of Al_2O_3 in the first series and 0·24 per cent. in the second.

Comparing 163 *B* and 165 *B*, the addition of 20 molecules of Na_2O to the glass results in an absorption difference of 0·66 per cent. The absorption difference in 163 *F* and 165 *F* is 0·83 for a rise of 20 molecules of Na_2O.

Excess of either lime or sodium oxide causes increased pot attack, and the Na_2O has a more corrosive action than the CaO.

Summary and General Conclusions.

(1) Glasses of the two types $100SiO_2,40Na_2O,x CaO$ and $100SiO_2,20Na_2O,x CaO$ have been investigated from the point of view of melting properties, corrosive action on pot clay, density, refractive index, devitrification, solubility, and weathering. In each series the molecular soda–silica content is a constant, there being only one variant oxide, namely, CaO. If corresponding glasses are taken in each series, the Na_2O becomes the variant oxide, the lime–silica being constant.

(2) All the glasses can be founded at temperatures above 1300°, and all exhibit attack upon pot clay.

(3) Increasing either CaO or Na_2O in these glasses causes increased pot attack, the Na_2O being the more corrosive in its action.

(4) The effect of pot attack and the volatilisation of the glasses is discussed, and the reason given why large melts have a higher refractive index than small melts made from the same batch.

(5) *The Density* of the glasses rises on increasing either CaO or Na_2O, the calcium oxide having the greater effect per molecule added.

(6) The increase in density per molecule of CaO added is not a constant. It is greatest where Na_2O is least, and it decreases as the CaO content increases. The rate of decrease is greater in the series containing the greater amount of Na_2O.

(7) The density is additive in character, but since equal additions of one particular oxide do not result in equal increases of density, the relation is not a simple one, being modified by the constitution of the glass.

(8) An attempt has been made to find whether there is a constant ratio between the molecular effects of CaO and Na_2O

upon glasses of this type, but the results are disappointing. This ratio of molecular effect increases as the CaO content increases in glasses of the type $100SiO_2,yNa_2O,xCaO$.

(9) The *Refractive Indices* for the *C*, *D*, and *F* lines have been determined. The refractive index increases as the CaO or Na_2O rises, the CaO having a greater effect than Na_2O per molecule added. In the series $100SiO_2,40Na_2O,xCaO$ the rise in the refractive index for the *D* line per molecule CaO added varies from 0·00158 to 0·00108 as x rises from 5 molecules to 40 molecules. For the series $100SiO_2,20Na_2O,xCaO$ the *D* line rises from 0·00236 to 0·00138 per molecule of CaO added, as x rises from 5 molecules to 40 molecules.

(10) The rate of increase in refractive index is greater per molecule of CaO added than per molecule Na_2O, and this rate of increase falls as the CaO content rises. The fall in rate of increase is greater in the series containing the greater amount of Na_2O.

(11) The rate of increase of refractive index is greatest for the *F* line and least for the *C* line of the spectrum.

(12) Where molecular lime–silica content is the same, the glass with the higher Na_2O content has the higher index.

(13) Refractive index is additive in character, but equal additions of CaO or Na_2O do not result in equal increases of index. Thus the additive relation is not a simple one, being influenced by the constitution of the glass.

(14) The refractive index of the glasses increases as the density increases, showing that it is influenced by the density.

(15) The *Total Dispersion* increases as the CaO or Na_2O increases. The rate of increase is greater in the series containing the lesser amount of Na_2O.

(16) Where the molecular lime–silica content is the same, the glass containing the higher Na_2O has the higher total dispersion.

(17) The ν *values* are higher in the series containing the lesser Na_2O, and decrease with increasing CaO or Na_2O.

(18) The ν values continually decrease as the refractive index for the *D* line increases.

(19) Increasing CaO or Na_2O lengthens both ends of the spectrum, and the lengthening effect of CaO is greater in the series with the lesser Na_2O.

(20) The addition of CaO or Na_2O causes the blue end of the spectrum to spread relatively more than the red.

(21) From the results obtained with these glasses, many other glasses of given optical constants can be made. The method of devising a batch for a given glass is shown.

(22) The *Devitrification* of the glasses is dealt with. Where the SiO_2 content is greater than 72 per cent., there is a tendency for the glass to devitrify, silica separating out under suitable conditions.

(23) Glasses of this type containing more than 10 per cent. of CaO easily devitrify under favourable conditions if the Na_2O content is greater than 20 per cent. Where the Na_2O content falls below 15 per cent., CaO may be added up to 15 per cent. before the glass shows a tendency to devitrify.

(24) The *Solubility* of the glasses in water decreases as the CaO or SiO_2 content rises, and increases with increasing Na_2O. The solubility of a glass depends largely upon its Na_2O content.

(25) The effect of lime in decreasing solubility falls as the CaO increases.

(26) Water attacks these glasses, and new insoluble compounds are formed. The attack is greatest in the glasses containing the most Na_2O. The difference between original weight of glass and the weight of the insoluble residue does not indicate the solubility of the glass.

(27) The *Durability* of the glasses is increased by the addition of SiO_2 and CaO, and decreased by the addition of Na_2O.

(28) All the glasses containing more than 15 per cent. Na_2O become dim on long exposure to atmospheric conditions.

(29) None of the glasses has a first-class durability value from an optical point of view, and so would be unsuitable for first-class optical work. The whole of the first series are debarred entirely, owing to bad weathering, even if the devitrification tendencies of the glasses containing more than 10 per cent. could be overcome. In the second series, all the glasses except those in the vicinity of the type $100SiO_2,20Na_2O,20CaO$ are debarred, owing to devitrification tendencies on slow cooling. Even this type and its near relations would only furnish glass with third-rate weathering properties.

(30) Where glass of the soda-lime–silicate type is required in the ordinary manufacture of jars, bottles, etc., glasses in the vicinity of $100SiO_2,20Na_2O,20CaO$ will be found quite useful. Such glasses contain up to 14 per cent. of CaO, an amount which at first sight may seem excessive. The modern tendency in glass manufacture, when dealing with the soda-lime–silica glasses, is to use a batch too high in silica and soda and too low in lime. In process of time, after continued use of cullet, owing to the volatilisation of the alkali, such a batch becomes difficult to found and work, and is liable to silica devitrification. To restore easy founding and working conditions, a considerable addition of alkali is made

to the batch, with the result that the final glass has a very poor durability. The best corrective for such batches is the addition of a suitable proportion of lime alone, or lime in conjunction with alkali, so that the final glass approximates to the molecular formula above. The use of batches containing high amounts of soda is becoming more and more the vogue with the increased use of automatic glass-making machinery, and it is to be deprecated. Glass articles containing an excess of Na_2O (more than 16 per cent.) have been shown to be low in durability, and where they are used as containers for liquid foodstuffs may seriously contaminate these materials. In addition, they become dull and dirty very quickly, and the merchant naturally prefers glasses which do not deteriorate on storing. The fact that lime is a most valuable flux, almost as powerful as soda, is often overlooked. The further fact requires emphasis that when soda is not present in an amount greater than 15 per cent., the tendency to devitrification of lime glasses is practically absent so long as the silica content is about 72 per cent.

Glasses in the vicinity of $100SiO_2,20Na_2O,20CaO$ contain from 70 to 72 per cent. of SiO_2, 15 to 16 per cent. of Na_2O, and 12 to 14 per cent. of CaO. Batches for the same would contain 700 to 720 parts of sand, 250 to 275 parts of sodium carbonate (58 per cent. alkali), and 250 to 214 parts of calcium carbonate (limestone). The best batch would probably be:—

Sand	720	parts
Sodium carbonate	260	,,
Calcium carbonate	230	,,

This batch would be easily and quickly founded, would provide a soft working "metal," and would give a glass of superior weathering properties for ordinary everyday use.

If salt-cake were used instead of sodium carbonate to provide the Na_2O in the glass, it would be necessary to substitute 350 parts of salt-cake for the 260 parts of sodium carbonate, at the same time adding charcoal or powdered coal, about 1 part to every 20 parts of salt-cake.

Where the manufacturer desires to use nitrate of soda when melting in pots, 15 parts of the nitrate should be substituted for every 10 parts of sodium carbonate. To provide the CaO in the glass, every 100 parts of the limestone (calcium carbonate) could be replaced by 74 parts of slaked lime, or 56 parts of ordinary quick lime.

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III.—*The Development of Various Types of Glass. Part III. The Interaction of Silica, Lime, and Potassium Oxide.*

By C. J. Peddle, M.Sc.

The commonest alkaline oxide which enters into glass is the oxide of sodium, and the previous paper* dealt with the influence of lime upon glasses containing this oxide. The oxide of potassium also enters largely into commercial glasses, particularly the better kinds, and the present paper deals with the influence of lime upon glasses containing potassium oxide and silica. The two series of melts carried out may be represented by the general molecular formulæ (1) $100SiO_2,40K_2O,xCaO$, and (2) $100SiO_2,20K_2O,xCaO$. It will be seen that they only differ from those of the corresponding Na_2O series in Part II, in that K_2O is substituted molecularly for Na_2O. The "nucleus" of the first series is 100 mols. of SiO_2, 40 mols. of K_2O, and of the second series 100 mols. of SiO_2, 20 mols. of K_2O, there being one variant oxide in each series, namely, CaO. The melting scheme in terms of molecular composition is shown below.

Table I.

Series $100SiO_2,40K_2O,xCaO$.				Series $100SiO_2,20K_2O,xCaO$.			
Melt. No.	Molecules. SiO_2.	Molecules. K_2O.	Molecules. CaO.	Melt No.	Molecules. SiO_2.	Molecules. K_2O.	Molecules. CaO.
167 *A*	100	40	5	168 *A*	100	20	5
B	do.	do.	10	*B*	do.	do.	10
C	do.	do.	15	*C*	do.	do.	15
D	do.	do.	20	*D*	do.	do.	20
E	do.	do.	30	*E*	do.	do.	30
F	do.	do.	40	*F*	do.	do.	40

The batch compositions expressed in terms of percentage oxide are shown in Table II. The sand, potassium carbonate, and calcium carbonate were from the same stock as used in melts described in Parts I and II. No nitrate or decoloriser was used.

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* This Journal, Trans., p. 20.

TABLE II.

Calculated Percentage Batch Composition.

Series $100SiO_2,40K_2O,xCaO$.					Series $100SiO_2,20K_2O,xCaO$.				
Melt No.	SiO_2.	K_2O.	CaO.	Al_2O_3 + Fe_2O_3.	Melt No.	SiO_2.	K_2O.	CaO.	Al_2O_3 + Fe_2O_3.
167 *A*	59·53	37·39	2·78	0·30	168 *A*	73·21	23·01	3·42	0·36
B	57·92	36·38	5·40	0·30	*B*	70·79	22·25	6·61	0·35
C	56·40	35·43	7·89	0·28	*C*	68·53	21·54	9·59	0·34
D	54·95	34·52	10·26	0·27	*D*	66·40	20·87	12·40	0·33
E	52·28	32·84	14·63	0·26	*E*	62·53	19·65	17·51	0·31
F	49·83	31·31	18·61	0·25	*F*	59·08	18·57	22·06	0·29

The melts were carried out as outlined in Part I, p. 6.

(1) Number of fillings = four, at half-hour intervals.

(2) Time of founding = three and a-half hours after last filling.

(3) Temperature = 1350° for last three hours.

The batches were more effervescent than the corresponding soda melts, and great care had to be exercised to prevent boiling over.

Results.

1. In the first series all the glasses were distinctly coloured, and the colour did not seem to be affected by the increase of lime.

2. In the second series the colour improved as the lime increased, except in the case of the last glass, which was quite yellow. The other five glasses were almost colourless.

3. The colour is deeper in the glasses containing the higher K_2O content, showing that K_2O has a considerable corrosive action upon pot clay.

(4) The glasses were more brilliant and less coloured than the corresponding Na_2O glasses.

(5) The hardness of the glasses increased as the CaO content increased. The glasses of the series containing the lesser K_2O were harder than those of the other series.

(6) The glasses were more brittle than those of the corresponding Na_2O series.

PROPERTIES OF THE GLASSES.

1. *Density.*

The following results were found for the densities of the two series.

TABLE III.

Series $100SiO_2,40K_2O,xCaO$.				Series $100SiO_2,20K_2O,xCaO$.			
Melt. No.	Molecules. CaO.	CaO. Per cent.	Density.	Melt No.	Molecules. CaO.	CaO. Per cent.	Density.
167 *A*	5	2·78	2·488	168 *A*	5	3·42	2·420
B	10	5·40	2·513	*B*	10	6·61	2·450
C	15	7·89	2·535	*C*	15	9·59	2·478
D	20	10·26	2·555	*D*	20	12·40	2·505
E	30	14·63	2·594	*E*	30	17·51	2·555
F	40	18·61	2·630	*F*	40	22·06	2·601

A comparison of the two series is shown in Fig. 1. Curves I and II indicate the relationship between molecular lime composition and density. Curves III and IV represent the relation between the percentage of CaO and the density.

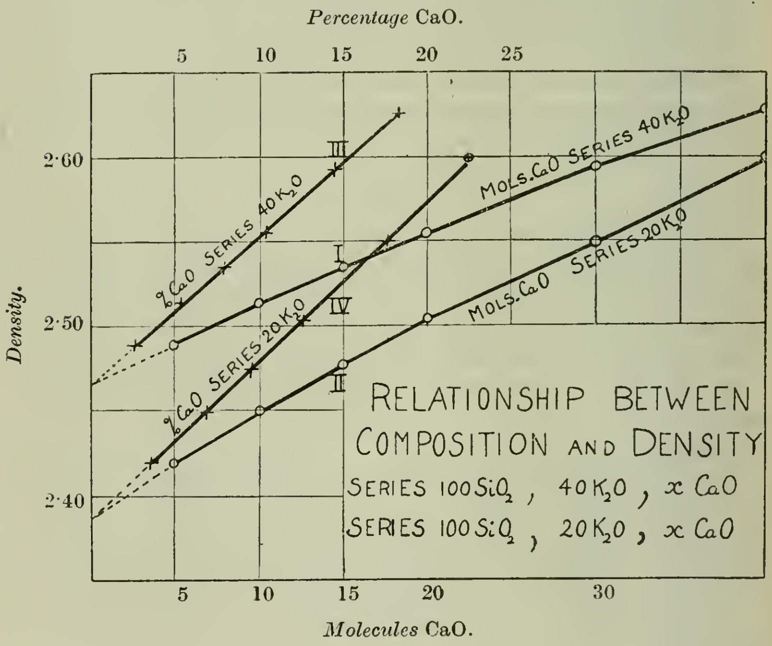

FIG. 1.

The following conclusions are drawn from these results:—

(1) The density is greater in the series containing the greater K_2O content.

(2) Increasing either the K_2O content or the CaO content increases the density.

(3) The rate of increase of density is greater in the series containing the lesser K_2O. The mean rise in density per molecule of CaO added is 0·0042 in the series $100SiO_2,40K_2O,x$CaO and 0·0053 in the series $100SiO_2,20K_2O,x$CaO. Thus CaO has the greater effect on the density of glasses of this type the richer the glass is in SiO_2 and the poorer in K_2O (see Table IV).

(4) The increase in density per molecule CaO added falls off in both series as the CaO rises (Table IV).

(5) The increase in density per 1 per cent. CaO added appears to be constant, being about 0·0089 in the first series and 0·0096 in the second (Table IV).

The following table states the effect of CaO upon the glasses at different concentrations of CaO.

TABLE IV.

Series $100SiO_2,40K_2O,x$CaO.			Series $100SiO_2,20K_2O,x$CaO.		
Molecules CaO.	$10^4 \times$ rise in density per molecule CaO added.	$10^4 \times$ rise in density per 1 per cent. CaO added.	Molecules CaO.	$10^4 \times$ rise in density per molecule CaO added.	$10^4 \times$ rise in density per 1 per cent CaO added.
5–10	50	96	5–10	60	94
10–15	44	86	10–15	56	93
15–20	40	84	15–20	54	96
20–30	39	89	20–30	50	98
30–40	36	90	30–40	46	101

(6) The results point to the fact that density is additive in its nature in these glasses, but is influenced to some extent by the constitution of the glass.

(7) Extension of the curves shows that the density of the glass $100SiO_2,20K_2O$ is 2·388, and the glass $100SiO_2,40K_2O$ is 2·465 (the corresponding $100SiO_2,40Na_2O$ glass has the same density*).

2. *Refractive Index.*

In the first series of glasses owing to the solubility of 167 *A* ($100SiO_2,40K_2O,5$CaO) no piece could be prepared for taking the refractive index. The values given in the tables for this glass are therefore extrapolated from the values obtained for the other glasses of the series.

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* The density of the glass $100SiO_2,20Na_2O$ is 2·365.

TABLE V.*

Melt No.	$x=$ mols. of CaO.	CaO. Per cent.	Refractive index, D line.	Total dispersion, $10^5\times(\eta_F-\eta_C)$.	ν.	Partial dispersion, $10^5\times(\eta_D-\eta_C)$.	Partial dispersion, $10^5\times(\eta_F-\eta_D)$.	β.
			Type $100SiO_2,40K_2O,xCaO$.					
167 *A*	5	2·78	1·5125	901	56·88	270	631	0·701
B	10	5·40	1·5179	914	56·66	272	642	0·702
C	15	7·89	1·5229	927	56·41	275	652	0·703
D	20	10·26	1·5277	938	56·26	278	660	0·704
E	30	14·63	1·5379	960	56·03	282	678	0·706
F	40	18·61	1·5475	978	55·98	286	692	0·708
			Type $100SiO_2,20K_2O,xCaO$.					
168 *A*	5	3·42	1·5011	828	60·52	248	580	0·700
B	10	6·61	1·5081	846	60·06	253	593	0·701
C	15	9·59	1·5151	865	59·55	258	607	0·702
D	20	12·40	1·5223	883	59·15	262	621	0·703
E	30	17·51	1·5355	922	58·08	272	650	0·705
F	40	22·06	1·5491	958	57·31	281	677	0·707

The above table gives the results for the refractive indices of the two series, and Fig. 2 shows these results diagrammatically.

Curves I and II represent the variation in η_D in the two series with increasing molecular CaO content. From these results the following conclusions are to be drawn:—

(1) Refractive index increases in both series with increased molecular CaO content.

(2) The rate of increase in η_D is greater in the series containing the lesser K_2O.

(3) The rate of increase per molecule CaO added appears constant in both series. In series I the refractive index for the *D* line rises 0·00100 per molecule CaO added, and in series II 0·00139 per molecule CaO added (see Table VI). Thus the refractive index for the *D* line is a direct additive function of the molecular CaO content in these two series. Since the rise in refractive index per molecule of CaO added is different in the two series, the constitution of the glass also plays a part in determining its value.

(4) Where the molecular CaO content is the same in the two series, the glass with the higher K_2O has the greater η_D until a CaO content of about 36 molecules is reached. Then the two glasses $100SiO_2,40K_2O,36CaO$ and $100SiO_2,20K_2O,36CaO$ have the same η_D value$=1·5442$.

The total dispersions of the two glasses are different, being

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* For further information regarding refractive index, see Part I, p. 10, and Part II. p. 25.

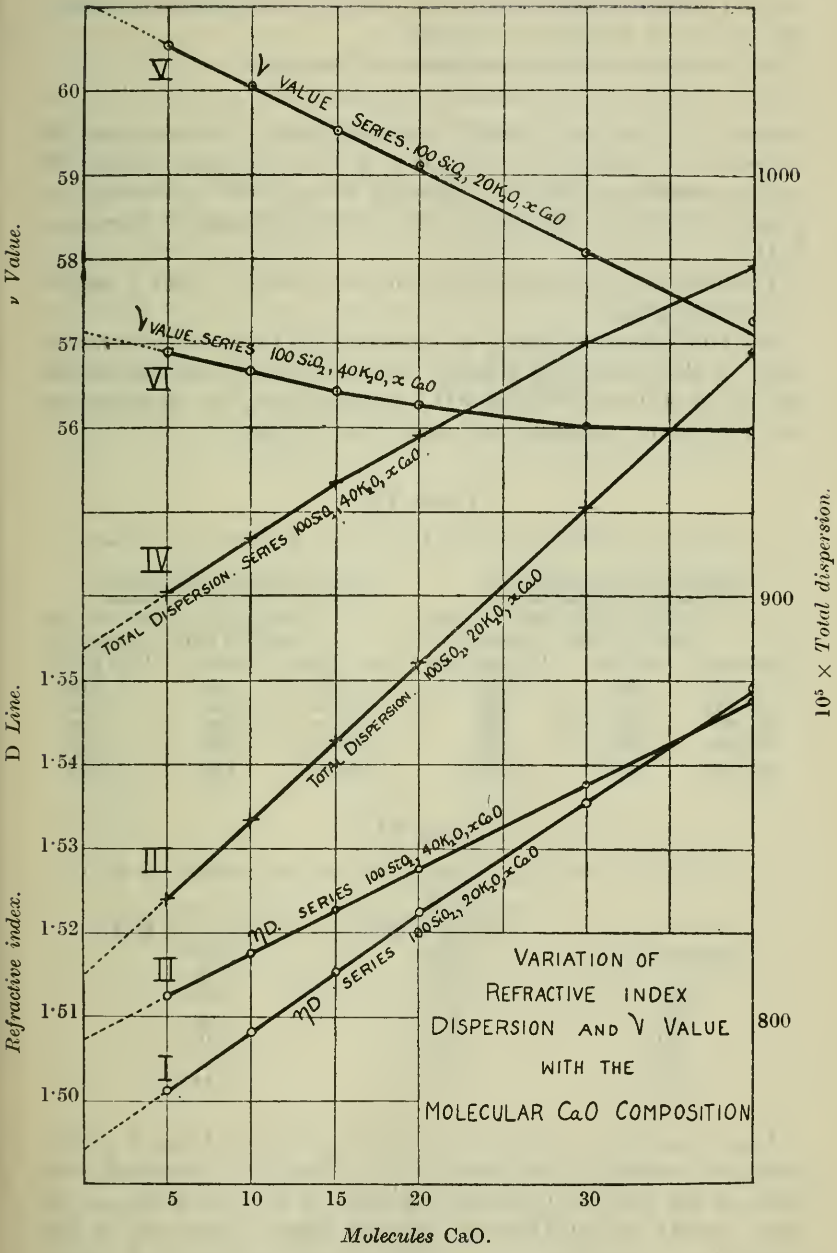
ν Value.
60
59
58
57
56
1·55
1·54
1·53
1·52
1·51
1·50
D Line.
Refractive index.
1000
900
800
10⁵ × Total dispersion.
V
ν VALUE SERIES. 100 SiO₂, 20K₂O, x CaO
VI
ν VALUE. SERIES 100 SiO₂, 40K₂O, x CaO
IV
TOTAL DISPERSION. SERIES 100SiO₂, 40K₂O, x CaO
III
TOTAL DISPERSION. 100SiO₂, 20K₂O, x CaO
II
ηD. SERIES 100 SiO₂, 40K₂O, x CaO
I
ηD SERIES 100SiO₂, 20K₂O, x CaO
VARIATION OF REFRACTIVE INDEX DISPERSION AND ν VALUE WITH THE MOLECULAR CaO COMPOSITION
5
10
15
20
30
Molecules CaO.

Fig. 2.

0·00971 and 0·00943 respectively, that is, the refractive indices for the *C* and *F* lines are different.

(5) In potash–lime–silicate glasses of the type

$$100SiO_2, xK_2O, yCaO,$$

where x lies between 20 and 40 molecules and y between 0 and 40 molecules, the greater the amount of K_2O in the glass the less will be the effect upon refractive index of adding CaO. Similarly, the greater the CaO in the glass the less will be the effect of increasing K_2O.

Probably this statement is true for all values of x and y capable of yielding glasses.

(6) The respective effects of CaO and K_2O upon the refractive index of the *D* line, for different concentrations of the two oxides, are shown in Tables VI and VII. The rises in η_D per molecule and per 1 per cent. addition are shown side by side.

TABLE VI.

Rise in Refractive Index of D *line due to addition of* CaO.

Series $100SiO_2, 40K_2O, xCaO$.			Series $100SiO_2, 20K_2O, xCaO$.		
Molecules.	$10^5 \times$ rise per mol. of CaO added.	$10^5 \times$ rise per 1 per cent. of CaO added.	Molecules.	$10^5 \times$ rise per mol. of CaO added.	$10^5 \times$ rise per 1 per cent. of CaO added.
5–10	108	206	5–10	140	219
10–15	100	201	10–15	140	234
15–20	96	203	15–20	145	256
20–30	102	233	20–30	132	258
30–40	96	241	30–40	136	299

TABLE VII.

Rise in Refractive Index for D *line due to addition of* K_2O.

Molecules CaO.	$10^5 \times$ rise in η_D per molecule of K_2O added.	$10^5 \times$ rise in η per 1 per cent. of K_2O added.
5	57	79
10	49	69
15	39	56
20	27	40
30	12	18
40	−8	−12

From these two tables it will be seen that CaO has a greater effect per molecule added than K_2O. There is no constant ratio between the effect of CaO and the effect of K_2O upon the η_D. In glass $100SiO_2, 20K_2O, 5CaO$ the effect of adding 1 molecule of CaO would be to raise the η_D by 0·00140, and the effect of adding 1 molecule of K_2O would be to raise it 0·00057, that is, a ratio value CaO to K_2O of 2·45.* In the glass $100SiO_2,40K_2O,10CaO$ the ratio value is 2·04.

Curves III and IV in Fig. 2 show the variation in total dispersion ($\eta_F - \eta_C$) in the two series with increase in the number of CaO molecules. The following is to be noted regarding total dispersion:—

(1) Total dispersion increases with increasing CaO.

(2) Where the molecular lime–silica contents of a glass are the same, increasing the K_2O content increases the total dispersion.

(3) The rate of increase of total dispersion with increasing CaO is greater in the series containing the lesser K_2O (Table VIII).

(4) This rate of increase tends to a constant value = 0·000037 per molecule of CaO added in the series $100SiO_2,20K_2O,x CaO$.

(5) Table VIII shows how the total dispersion in the two series is affected by the addition of (1) a molecule CaO, (2) 1 per cent. of CaO. Table IX shows the effect of K_2O on total dispersion.

TABLE VIII.

Effect on Total Dispersion by the Addition of CaO.

Series $100SiO_2,40K_2O,x CaO$.			$100 SiO_2,20K_2O,x CaO$.		
	10^6 × mean rise in total dispersion.			10^6 × mean rise in total dispersion.	
Molecules of CaO.	Per mol. of CaO added.	Per 1 per cent. of CaO added.	Molecules of CaO.	Per mol. of CaO added.	Per 1 per cent. of CaO added.
5–10	26	49	5–10	36	56
10–15	26	52	10–15	38	64
15–20	22	47	15–20	36	64
20–30	22	50	20–30	39	76
30–40	18	45	30–40	36	79

TABLE IX.

Effect on Total Dispersion caused by the Addition of K_2O.

Molecules CaO.	10^6 × rise in total dispersion per mol. of K_2O added.	10^6 × rise in total dispersion per 1 per cent. of K_2O added.
5	36	51
10	34	48
15	31	45
20	27	40
30	19	29
40	10	16

(6) Comparison of the two tables above shows that the effect of CaO upon total dispersion decreases at a much less rapid rate than the effect of K_2O as the lime content increases.

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* The corresponding ratio CaO to Na_2O in similar soda–lime–silicate glass is 3·57 (Part II, p. 28).

(7) Total dispersion in these series is an additive function of the CaO, but the relation is not simple, and is influenced by the constitution of the glass.

Curves V and VI in Fig. 2 show the ν values of the glasses in the two series. It will be seen that the ν values are greater in the series containing the lesser K_2O, and decrease with an increase in CaO. The ν values continually decrease as the refractive index for the *D* line increases.

A study of the partial dispersion $(\eta_D - \eta_C)$ and $(\eta_F - \eta_D)$ shows the following:—

(1) Increasing CaO in a glass lengthens both the red and blue ends of the spectrum.

(2) The lengthening effect is greater in the series containing the lesser K_2O. Thus in increasing from 5 molecules to 40 molecules of CaO in the series $100SiO_2,40K_2O,x CaO$ the partial dispersion *D* to *F* increases 0·00061. In the series $100SiO_2,20K_2O,x CaO$ the corresponding increase is 0·00097. Similarly, the partial dispersion *C* to *D* increases 0·00016 in the first series and 0·00033 in the second.

(3) The fact that the partial dispersion *C* to *D* and *D* to *F* both increase as the CaO content rises, that is, as the refractive index rises, proves that the addition of CaO increases the refractive index for the *F* line more than that of the *D* line, and the refractive index of the *D* line more than that of the *C* line. Thus, with increasing CaO, the rate of increase of refractive index falls most in the *C* line and least in the *F* line.

From the β values $\left(\frac{\eta_F - \eta_D}{\eta_F - \eta_C}\right)$ it will be seen that increasing CaO causes the blue end of the spectrum to spread relatively more than the red, that is, the β-value rises as the CaO rises.

A comparison of the β-values in the two series proves that the relative spread is greater in the series containing the greater amount of K_2O, that is, the β-value rises as the K_2O rises.

A continuation of the curves in Fig. 2 gives the values *:—
$\eta_D = 1·5073$, $F - C = 0·00888$, $\nu = 57·1$ for the glass $100SiO_2,40K_2O$, and $\eta_D = 1·4937$, $F - C = 0·00809$, $\nu = 61·2$ for the glass $100SiO_2,20K_2O$.

3. *Devitrification.*

(1) In cooling from 1350° to the ordinary temperature in twelve hours there were no signs of devitrification in either series. With slower cooling, namely, from 1200° to the ordinary temperature in

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* See Part I, p. 18.

twelve hours, the glass $100SiO_2,20K_2O,40CaO$ devitrified, white, spherical lumps of calcium silicate being formed. In none of the glasses was there any signs of a separation of silica.

(2) The usual test for devitrification (heating small pieces to 900°, keeping them at that temperature for six hours, and then slowly cooling during twelve hours) was carried out and the following results obtained.

TABLE X.

Melt No.	Mols. CaO.	Percentage.		Results.
		CaO.	SiO_2.	
		Series $100SiO_2,40K_2O,xCaO$.		
167 *A*	5	2·78	59·53	Devitrified before melting down.
B	10	5·40	57·92	do.
C	15	7·89	56·40	do.
D	20	10·26	54·95	Partly devitrified and just melted.
E	30	14·63	52·28	No devitrification. Melted down.
F	40	18·61	49·83	do.
		Series $100SiO_2,20K_2O,xCaO$.		
168 *A*	5	3·42	73·21	No devitrification. Not melted. Covered with skin.
B	10	6·61	70·79	No devitrification. do. do.
C	15	9·59	68·53	No devitrification. do. do.
D	20	12·40	66·40	No devitrification. Melted. do.
E	30	17·51	62·5	No devitrification. do. do.
F	40	22·06	59·08	Devitrified before melting. do.

In the first series, where the K_2O content is greater than 34 per cent., devitrification can easily be induced, a potassium silicate probably separating out. Increasing the CaO or the SiO_2 deters this separation. In the second series, devitrification is only apparent in the glass containing more than 20 per cent. CaO, calcium silicate then separating out.

It should be noted in this second series that increasing the CaO lowers the melting point of the glass considerably.

4. *Solubility.*

Solubility tests were carried out as outlined previously. The numbers under the heading "H_2SO_4" represent the number of milligrams of H_2SO_4 required to neutralise the base dissolved out of 100 grams of glass. Under the heading "K_2O" the figures represent milligrams K_2O equivalent to this H_2SO_4 value. "Weight dissolved" is obtained by subtracting weight of undissolved matter from weight of original glass. As before stated, this is a very untrustworthy figure, as insoluble compounds are sometimes formed due to the reaction between water and the glass.

TABLE XI.

Series $100SiO_2,40K_2O,xCaO$.				Series $100SiO_2,20K_2O,xCaO$.			
	Milligrams per 100 grams.				Milligrams per 100 grams.		
Melt No.	Weight dissolved.	H_2SO_4.	Equiv. K_2O.	Melt. No.	Weight dissolved.	H_2SO_4.	Equiv. K_2O.
167 *A*	58,870	28,320	27,260	168 *A*	5494	5348	5145
B	58,192	27,600	26,560	*B*	2448	1438	1384
C	21,556	20,360	19,590	*C*	1568	963	927
D	8040	8638	8312	*D*	1244	604	581
E	874	5142	4948	*E*	876	355	342
F	236	2194	2111	*F*	748	303	291

(1) In both series the solubility falls as the CaO content rises.

(2) For equivalent CaO content the glass containing the least K_2O is the least soluble.

(3) The value of CaO in rendering a glass insoluble is strikingly brought out in both series, as is also the powerful effect of K_2O in causing solubility. Thus the glass 167 *D*, containing 34·5 per cent. of K_2O, is far more soluble than 168 *A*, containing 23 per cent. of K_2O, although the former contains 10·76 per cent. of CaO and the latter only 3·42 per cent.

(4) In the first series there is undoubted evidence of reaction having taken place between the water and the powdered glass to form insoluble compounds. In the case of the first glass quite a large amount of gelatinous substance was formed, and in all the other glasses gelatinous material was present after boiling, the amount getting less as the CaO increased.

5. *Durability*.

(1) The solubility numbers given under the heading "milligrams H_2SO_4 per 100 grams" in Table XI indicate that durability in these glasses increases with increasing CaO content, and in contrasting the two series where the molecular CaO content is the same, the glass containing the higher K_2O is the less durable. Classifying the glasses under the standards of durability worked out previously,* it will be seen that none of the glasses in the first series could be used for optical instruments as the solubility value is much higher than the limits of Class V. In the second series, glass $100SiO_2,20K_2O,15CaO$ is in Class V, glass

$$100SiO_2,20K_2O,20CaO$$

in Class IV, and glasses $100SiO_2,20K_2O,30CaO$ and

$$100SiO_2,20K_2O,40CaO$$

in Class II. Thus none of these glasses would pass muster for first-class optical work even if they could be made without devitrification.

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* See Part II, p. 39.

(2) The exposure test results for durability are stated in Table XII.

TABLE XII.

No.	Exposed 100 hours to air saturated with moisture at 18°.	Exposed one year to ordinary air (closed room).
	Series $100SiO_2,40K_2O,xCaO$.	
167 *A*	Forms pool of liquid and covered with crinkled skin.	Covered with thick white, opaque skin.
B	Covered with thick film of oily liquid.	Dulled over and almost opaque.
C	Covered with thin film of liquid.	Covered with a very bad film.
D	Covered with spots of liquid.	Covered with bad film.
E	Faintly dimmed.	Filmed over, but not badly.
F	Unaffected.	Faintly filmed.
	Series $100SiO_2,20K_2O,xCaO$.	
168 *A*	Slightly greasy.	Faintly filmed.
B	Unaffected.	Very faintly filmed.
C	do.	Very slight signs of filming.
D	do.	Unaltered.
E	do.	do.
F	do.	do.

(1) The results in the preceding table bear out those of the solubility test.

(2) Where the H_2SO_4 value in the solubility test is less than 2000 milligrams per 100 grams there is no visible effect on the glass after exposure to moist air for one hundred hours at 18°.

Summary and General Conclusions.

(1) Glasses of the two types $100SiO_2,40K_2O,xCaO$ and

$100SiO_2,20K_2O,xCaO$

have been investigated. In each series the molecular silica–potash content is the same, the only variant being the molecular lime content.

(2) All the glasses can be founded at temperatures above 1300°, and exhibit corrosive action upon pot clay.

(3) The *Density* of the glasses rises on increasing either the CaO or the K_2O content, the CaO having the greater effect per molecule added.

(4) The increase in density per molecule added is not a constant. It is greatest where the K_2O is least.

(5) Density is additive in character, but since equal additions of one particular oxide do not result in equal increases of density,

the relation is not a simple one, being modified by the constitution of the glass.

(6) The *Refractive Indices* for the *C*, *D*, and *F* lines have been found. The refractive index increases with the addition of both CaO and K_2O, the first-named oxide having the greater effect per molecule. In the series $100SiO_2,40K_2O,xCaO$ the rise of refractive index for the *D* line is 0·00100 for every molecule of CaO added. In the second series the rise is 0·00139.

(7) The rate of increase in refractive index is greatest for the *F* line and least for the *C* line, of the three lines measured.

(8) Where the molecular lime–silica content is the same, the glass with the higher K_2O content has the higher refractive index.

(9) Refractive index is additive in character, but since equal additions of CaO and K_2O do not result in equal increases of refractive index, constitutive influences come into play.

(10) The refractive index increases with the density, showing that it is influenced by the density.

(11) The *Total Dispersion* increases as the proportion of CaO or K_2O is increased. The rate of increase is greater in the series containing the lesser amount of K_2O.

(12) Where the molecular lime–silica content is the same, the glass containing the most K_2O has the highest total dispersion.

(13) The *ν values* are higher in the series containing the lesser K_2O, and decrease with increasing CaO and K_2O.

(14) These ν values continually decrease as the refractive index for the *D* line increases.

(15) Increasing the CaO or K_2O lengthens both ends of the spectrum, and the lengthening effect of CaO is greater the smaller the amount of K_2O in the glass.

(16) The addition of CaO or K_2O causes the blue end of the spectrum to be spread more than the red.

(17) The *Devitrification* of the glasses is dealt with. Where the K_2O content is greater than 34 per cent., devitrification can be easily induced.

(18) The *Solubility* of the glasses in water decreases as the CaO or SiO_2 value rises, but increases rapidly as the K_2O is increased.

(19) The *Durability* of the glasses is increased by the addition of CaO and SiO_2, and is decreased by the addition of K_2O.

(20) None of the glasses is of first-class durability from an optical glass point of view, and all would be unsuitable for the best optical instruments.

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Derby Crown Glass Co., Ltd.,
Little Chester, Derby.

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Barnsley.

IV.—*The Development of Various Types of Glass. Part IV. The Interaction of Silica, Lime, and the Oxides of Sodium and Potassium.*

By C. J. PEDDLE, M.Sc.

THE two preceding papers dealt with the interaction of silica and lime, first with sodium oxide and secondly with potassium oxide. The present paper deals with glasses containing both the alkaline oxides in conjunction with lime and silica. Thus the "nucleus" of Series I is 100 molecules of SiO_2, 20 molecules of Na_2O, 20 molecules of K_2O, and of Series II, 100 molecules of SiO_2, 10 molecules of Na_2O, 10 molecules of K_2O.

The melting scheme was as under:—

TABLE I.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.					Series $100SiO_2,10Na_2O,10K_2O,xCaO$.				
Melt No.	Mols. SiO_2.	Mols. Na_2O.	Mols. K_2O.	Mols. CaO.	Melt No.	Mols. SiO_2.	Mols. Na_2O.	Mols. K_2O.	Mols. CaO.
169 *A*	100	20	20	5	170 *A*	100	10	10	5
B	,,	,,	,,	10	*B*	,,	,,	,,	10
C	,,	,,	,,	15	*C*	,,	,,	,,	15
D	,,	,,	,,	20	*D*	,,	,,	,,	20
E	,,	,,	,,	30	*E*	,,	,,	,,	30
F	,,	,,	,,	40	*F*	,,	,,	,,	40

The first series of melts contained 40 molecules of alkaline oxides and the second series 20 molecules, so that comparison could be made with the glasses already dealt with.

Table II gives the percentage batch compositions in terms of oxides. The batch materials were the same as those used in making up the soda–lime–silicate and potash–lime–silicate series. No nitrate or decoloriser was used.

TABLE II.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.						Series $100SiO_2,10Na_2O,10K_2O,xCaO$.					
Melt No.	SiO_2.	Na_2O.	K_2O	CaO.	Al_2O_3 + Fe_2O_3.	Melt No.	SiO_2.	Na_2O.	K_2O	CaO.	Al_2O_3 + Fe_2O_3.
169 *A*	63·59	13·14	19·99	2·97	0·31	170 *A*	76·21	7·87	11·98	3·56	0·38
B	61·76	12·77	19·41	5·76	0·30	*B*	73·59	7·60	11·56	6·88	0·37
C	60·02	12·40	18·87	8·41	0·30	*C*	71·15	7·35	11·18	9·96	0·36
D	58·40	12·06	18·35	10·90	0·29	*D*	68·88	7·12	10·81	12·85	0·34
E	55·38	11·44	17·41	15·50	0·27	*E*	64·71	6·69	10·17	18·11	0·32
F	52·66	10·88	16·55	19·65	0·26	*F*	61·02	6·31	9·59	12·78	0·30

The melts were carried out as outlined in Part I, p. 6.

Results.

(1) The glasses of Series I were all coloured distinctly, the colour tending to deepen as the CaO content increased. In Series II the glasses were only very faintly coloured, although in this series, again, the colour tended to deepen as the CaO content increased.

(2) The above result proves that pot attack is more severe in the series of glasses containing the higher amount of alkaline oxides.

(3) In colour, hardness, brittleness, and brilliancy the glasses were intermediate between those of the soda–lime–silica and potash–lime–silica series discussed in Parts II and III. The glasses were more coloured, less brittle, and less brilliant than the corresponding glasses of the potash series.

PROPERTIES.

1. *Density.*

The following were the results found for the densities of the glasses:—

TABLE III.

Series $100\mathrm{SiO_2},20\mathrm{Na_2O},20\mathrm{K_2O},x\mathrm{CaO}$.				Series $100\mathrm{SiO_2},10\mathrm{Na_2O},10\mathrm{K_2O},x\mathrm{CaO}$.			
Melt No.	Mols. CaO.	CaO per cent.	Density.	Melt No.	Mols. CaO.	CaO per cent.	Density.
169 *A*	5	2·97	2·502	170 *A*	5	3·56	2·415
B	10	5·76	2·529	*B*	10	6·88	2·450
C	15	8·41	2·554	*C*	15	9·96	2·485
D	20	10·90	2·574	*D*	20	12·85	2·523
E	30	15·50	2·619	*E*	30	18·11	2·585
F	40	19·65	2·657	*F*	40	22·78	2·626

A comparison of the two series is shown diagrammatically in Fig. 1. Curves I and II represent the relationship between molecular CaO composition and density, Curves III and IV the relationship between the percentage of CaO present and density.

The following conclusions are to be drawn:—

(1) The density is greater in the series containing the greater amount of alkaline oxides.

(2) Increasing the amount of either CaO or alkaline oxide increases the density.

(3) The rate of increase of density is greater in the series containing the lesser amount of alkaline oxides. Thus in the first series the mean rise in density per molecule of CaO added is

0·0045, and in the second series it is 0·0064. Thus CaO has the greater effect upon density in glasses of this type the richer they are in silica and the poorer in alkaline oxides.

(4) The following table gives the effect of CaO upon the density of these glasses for different concentrations of CaO.

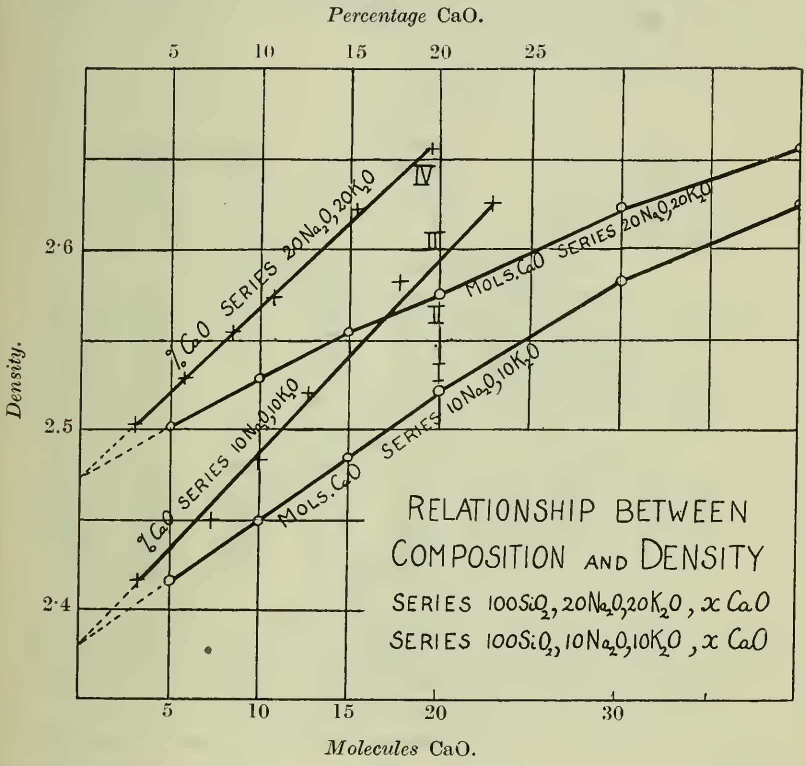

FIG. 1.

TABLE IV.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.			Series $100SiO_2,10Na_2O,10K_2O,xCaO$.		
Molecules of CaO.	$10^4\times$ rise in density per mol. of CaO added.	$10^4\times$ rise in density per 1 per cent. of CaO added.	Molecules of CaO.	$10^4\times$ rise in density per molecule of CaO added.	$10^4\times$ rise in density per 1 per cent. of CaO added
5—10	54	97	5—10	70	104
10—15	50	94	10—15	70	113
15—20	40	80	15—20	76	131
20—30	45	97	20—30	62	118
30—40	38	91	30—40	41	88

Extension of the curves gives the density of the glass $100SiO_2,20Na_2O,20K_2O$ as 2·472, and the density of the glass $100SiO_2,10Na_2O,10K_2O$ as 2·377.*

2. *Refractive Index.*

The glasses were all sufficiently durable to yield pieces suitable for taking refractive indices on the Pulfrich refractometer, and Table V shows the results.

TABLE V.

Melt No.	Mols. of CaO.	CaO per cent.	η_D.	Total dispersion, $10^5 \times (F-C)$.	ν.	Partial dispersion, $10^5 \times (D-C)$.	Partial dispersion, $10^5 \times (F-D)$.	β.
Series $100SiO_2,20Na_2O,20K_2O,x$CaO.								
169 *A*	5	2·97	1·5115	900	56·83	269	631	0·701
B	10	5·76	1·5186	915	56·65	273	642	0·702
C	15	8·41	1·5255	933	56·32	277	656	0·703
D	20	10·90	1·5314	948	56·06	281	667	0·704
E	30	15·50	1·5428	977	55·55	287	690	0·706
F	40	19·65	1·5514	1002	55·03	293	709	0·708
Series $100SiO_2,10Na_2O,10K_2O,x$CaO.								
170 *A*	5	3·56	1·4992	823	60·65	247	576	0·700
B	10	6·88	1·5086	843	60·33	252	591	0·701
C	15	9·96	1·5177	865	59·83	258	607	0·702
D	20	12·85	1·5253	884	59·42	263	621	0·703
E	30	18·11	1·5401	928	58·20	274	654	0·705
F	40	22·78	1·5528	966	57·22	283	683	0·707

Fig. 2 shows these results diagrammatically. Curves I and II show the variation of the refractive index for the *D* line in the two series with increasing molecular CaO content. The following conclusions are to be drawn from these results:—

(1) The refractive index increases in both series as the CaO increases.

(2) The rate of increase in η_D is greater in the series containing the smaller quantity of alkaline oxides (see Table VI).

(3) Where the molecular CaO content is the same in glasses of the two series, the glass with the higher alkaline oxide content has the greater refractive index for the *D* line until a molecular content about 37 molecules of CaO is reached. Then the two glasses $100SiO_2,20Na_2O,20K_2O,37CaO$ and

$$100SiO_2,10Na_2O,10K_2O,37CaO$$

have the same refractive index for the *D* line, namely, 1·5490.

It should be noted that the total dispersions are different in the

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* See Part I, p. 19.

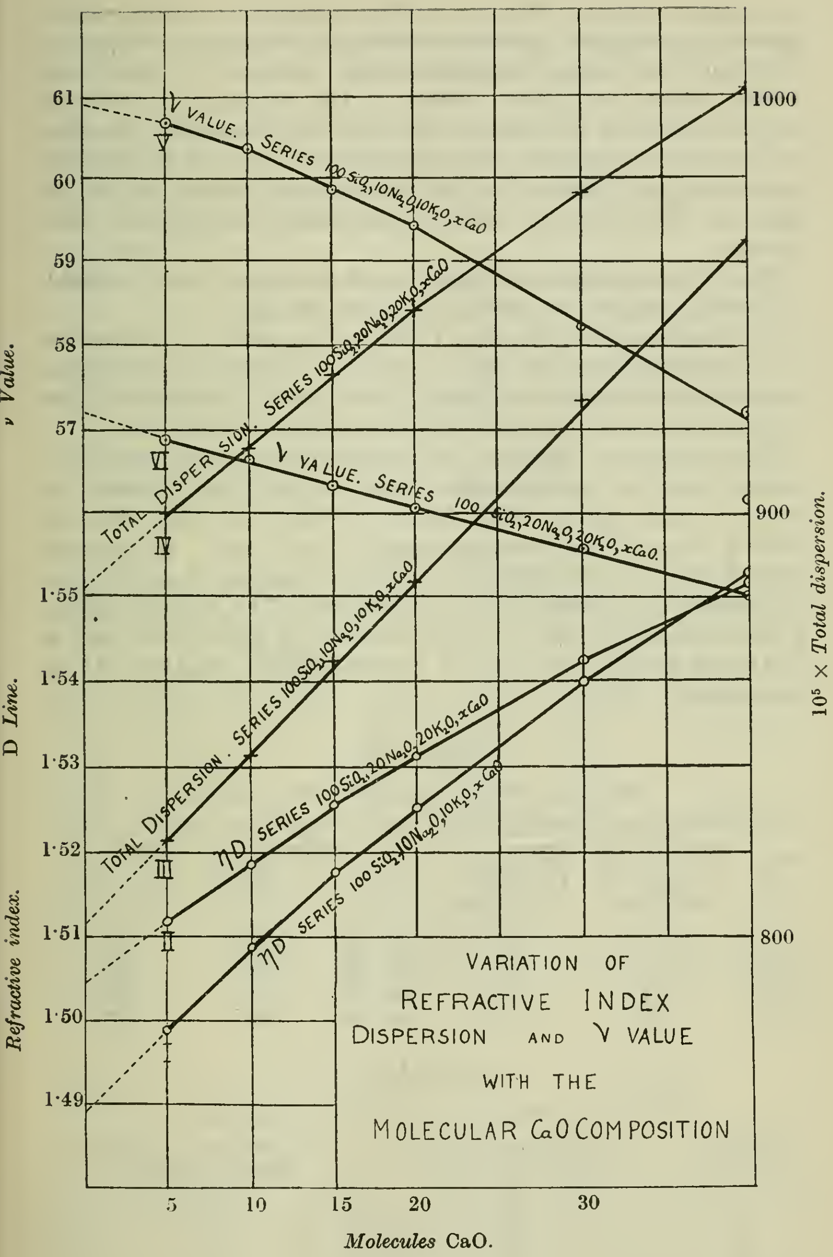
ν VALUE. SERIES 100 SiO$_2$,10Na$_2$O,10K$_2$O,xCaO
TOTAL DISPERSION. SERIES 100SiO$_2$,20Na$_2$O,20K$_2$O,xCaO
ν VALUE. SERIES 100 SiO$_2$,20Na$_2$O,20K$_2$O,xCaO.
TOTAL DISPERSION. SERIES 100SiO$_2$,10Na$_2$O,10K$_2$O,xCaO
ηD SERIES 100SiO$_2$,20Na$_2$O,20K$_2$O,xCaO
ηD SERIES 100 SiO$_2$,10Na$_2$O,10K$_2$O,xCaO
V
VI
IV
III
II
VARIATION OF
REFRACTIVE INDEX
DISPERSION AND ν VALUE
WITH THE
MOLECULAR CaO COMPOSITION
61
60
59
58
57
ν Value.
1·55
1·54
1·53
1·52
1·51
1·50
1·49
D Line.
Refractive index.
1000
900
800
10^5 × Total dispersion.
5
10
15
20
30
Molecules CaO.

FIG. 2.

two glasses. being 0·00995 and 0·00955 respectively. Thus the two glasses have different refractive indices for the *C* and *F* lines.

(4) In the soda–potash–lime–silica glasses of the type $100SiO_2,xNa_2O,xK_2O,yCaO$, where x lies between 10 molecules and 20 molecules, the greater the Na_2O,K_2O content of the glass the less will be the effect upon the refractive index of adding CaO. Conversely, the greater the CaO in the glass the less will be the effect on the refractive index of increasing the alkaline oxide content.

Possibly this statement is true for all values of x and y capable of yielding glasses, but further data are needed.

(5) The respective effects of CaO and the alkaline oxides upon the refractive index for the *D* line for different concentrations of the oxides are shown in Tables VI and VII. The rises in η_D per molecule and per 1 per cent. addition are shown side by side.

From these two tables it will be noted that the CaO has a greater effect per molecule added than the Na_2O,K_2O. There is no constant ratio between the effect of CaO and the effect of Na_2O,K_2O upon the refractive index of the *D* line. In the glass $100SiO_2,10Na_2O,10K_2O,5CaO$ the effect of adding 1 molecule of CaO would be to raise the η_D by 0·00188. The effect of adding 1 molecule of Na_2O,K_2O 0·00062, that is, a ratio value CaO to Na_2O,K_2O of 3·03. In the glass $100SiO_2,20Na_2O,20K_2O,10CaO$ the ratio value is 2·76.

TABLE VI.

Rise in η_D *due to the Addition of* CaO.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.			Series $100SiO_2,10Na_2O,10K_2O,xCaO$.		
Mols. of CaO.	10^5 × rise per molecule of CaO added.	10^5 × rise per 1 per cent. of CaO added.	Mols. of CaO.	10^5 × rise per molecule of CaO added.	10^5 × rise per 1 per cent. of CaO added.
5—10	142	254	5—10	188	283
10—15	138	260	10—15	182	295
15—20	118	237	15—20	152	263
20—30	114	248	20—30	148	281
30—40	86	207	30—40	127	272

TABLE VII.

Rise in η_D *due to the Addition of* Na_2O,K_2O.

Molecules of CaO.	10^5 × rise per mol. of Na_2O,K_2O added.	10^5 × rise per 1 per cent. of Na_2O,K_2O added.
5	62	92
10	50	77
15	39	61
20	31	49
30	14	23
40	−7	−11

Curves III and IV in Fig. 2 show the variation in the total dispersion $(\eta_F - \eta_C)$ in the two series with increasing molecular CaO content. The following points are to be noted respecting total dispersion.

(1) In both series total dispersion increases with increasing CaO content.

(2) In glasses where the molecular $CaO–SiO_2$ content is the same, increasing the amount of alkaline oxide increases the total dispersion.

(3) Rate of increase of total dispersion with increasing CaO is greater in the series containing the smaller amount of alkaline oxide.

(4) Table VIII shows how total dispersion is affected (1) by the addition of one molecule of CaO, (2) by the addition of 1 per cent. of CaO, for different CaO concentrations.

(5) Table IX shows the effect of Na_2O,K_2O upon total dispersion per molecule and per 1 per cent. addition.

TABLE VIII.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.			Series $100SiO_2,10Na_2O,10K_2O,xCaO$.		
	$10^6 \times$ mean rise in total dispersion.			$10^6 \times$ mean rise in total dispersion.	
Mols. of CaO.	Per mol. of CaO added.	Per 1 per cent. of CaO added.	Mols. of CaO.	Per mol. of CaO added.	Per 1 per cent. of CaO added.
5—10	30	54	5—10	40	60
10—15	36	68	10—15	44	71
15—20	30	60	15—20	38	66
20—30	29	63	20—30	44	83
30—40	25	60	30—40	38	81

TABLE IX.

Molecules of CaO.	$10^6 \times$ rise in total dispersion per molecule of Na_2O,K_2O added.	$10^6 \times$ rise in total dispersion per 1 per cent. of Na_2O,K_2O added.
5	39	58
10	36	55
15	34	53
20	32	51
30	25	41
40	18	31

(6) Comparison of the two tables shows that the effect of CaO upon total dispersion decreases at a much less rapid rate than the effect of Na_2O,K_2O as the amount of CaO in the glass rises.

Curves V and VI in Fig. 2 show the ν values in the two series. It will be seen that the ν values are greater in the series containing the lesser Na_2O,K_2O, and decrease with increasing CaO. The ν values continually decrease as the η_D values increase.

The following points regarding the partial dispersions $(\eta_D - \eta_C)$ $(\eta_F - \eta_D)$ are to be emphasised:—

(1) Both the red and the blue ends of the spectrum are lengthened by increasing the CaO content of these glasses.

(2) The lengthening effect is greater in the series containing the lesser amount of alkaline oxides. In increasing from 5 molecules to 40 molecules CaO in the series

$$100SiO_2,20Na_2O,20K_2O,xCaO,$$

the partial dispersion D to F increases 0·00078. In the series $100SiO_2,10Na_2O,10K_2O,xCaO$ the corresponding increase is 0·00107. Similarly, the partial dispersion C to D increases only 0·00024 in the first series as against 0·00036 in the second.

(3) The fact that the partial dispersions C to D and D to F both increase as the CaO content increases proves that the addition of CaO in these glasses raises the refractive index of the F line more than that of the D line and of the D line more than the C line. Thus with increasing CaO the rate of increase of refractive index falls most in the C line and least in the F line.

It will be seen from the β values that increasing the CaO content causes the blue end of the spectrum to spread relatively more than the red end, that is, the β value rises as the CaO rises.

A comparison of the β values of the two series proves that the relative spread of the blue end of the spectrum is greater in the series containing the greater amount of alkaline oxide, or, the β value rises as the Na_2O,K_2O amount rises.

A continuation of the Curves I, III, and V gives the values $\eta_D = 1{\cdot}5044$, $F - C = 0{\cdot}00882$, $\nu = 57{\cdot}15$ for the glass.

$$100SiO_2,20Na_2O,20K_2O.$$

Curves II, IV, and VI yield values for the glass

$$100SiO_2,10Na_2O,10K_2O,$$

$\eta_D = 1{\cdot}4892$, $F - C = 0{\cdot}00803$, $\nu = 60{\cdot}9$.*

3. *Devitrification.*

(1) In cooling from 1350° to the ordinary temperature in twelve hours there were no signs of devitrification. In a second series cooled more slowly from 1200° to the ordinary temperature in twelve hours, the glass $100SiO_2,10Na_2O,10K_2O,40CaO$ devitrified, spheroidal bunches of white crystals being formed.

(2) A further test of devitrification was carried out, small

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* See Part I., page 19.

pieces of each glass being kept at a temperature of 900° for six hours, and then slowly cooled over twelve hours to the ordinary temperature. The results are shown in Table X.

TABLE X.

Melt No.	Mols. CaO.	Per cent. of CaO	Per cent. of SiO_2.	Results.
				Series $100SiO_2,20Na_2O,20K_2O,xCaO$.
169 *A*	5	2·97	63·59	Glass melts. Covered with translucent skin. No devitrification.
B	10	5·76	61·76	Glass melts. Covered with translucent skin. No devitrification.
C	15	8·41	60·02	Glass melts. Covered with thick, white film of needle-like crystals.
D	20	10·90	58·40	Glass melts. Fully devitrified. Porcelain-like.
E	30	15·50	55·38	Glass melts. Fully devitrified. Porcelain-like.
F	40	19·65	52·66	Glass melts. Fully devitrified. Porcelain-like.
				Series $100SiO_2,10Na_2O,10K_2O,xCaO$.
170 *A*	5	3·56	76·21	Not melted. Translucent film. No devitrification.
B	10	6·88	73·59	Not melted. Translucent film. No devitrification.
C	15	9·96	71·15	Not melted. Translucent film. No devitrification.
D	20	12·85	68·88	Not melted. Translucent film. No devitrification.
E	30	18·11	64·71	Not melted. Devitrifies. White porcelain appearance.
F	40	22·78	61·02	Not melted. Devitrifies. White porcelain appearance.

In the first series glasses containing more than 9 per cent. of CaO can easily be devitrified. In the second series as much as 13 per cent. of CaO can be introduced without devitrification. It should also be noted in the second series that there is no silica separation, although the glass 170 *A* contains more than 76 per cent. of SiO_2.

4. *Solubility.*

Solubility tests as outlined previously were carried out, and Table XI shows the results obtained. The numbers under the heading "H_2SO_4" represent the number of milligrams of H_2SO_4 required to neutralise the base dissolved out of 100 grams of glass. Under the heading Na_2O,K_2O the figures represent milligrams of alkaline oxide equivalent to this H_2SO_4, assuming that the alkaline oxides are dissolved out in the ratio of their molecular weights $Na_2O \div K_2O = 62 \div 93$. "Weight dissolved" is obtained by subtracting weight of undissolved matter from weight of original glass.

TABLE XI.

Series $100SiO_2,20Na_2O,20K_2O,xCaO$.				Series $100SiO_2,10Na_2O,10K_2O,xCaO$.			
	Milligrams per 100 grams.				Milligrams per 100 grams.		
Melt No.	Weight dissolved.	H_2SO_4.	Equiv. Na_2O,K_2O.	Melt No.	Weight dissolved.	H_2SO_4.	Equiv. Na_2O,K_2O.
169 *A*	58,972	30,219	25,140	170 *A*	2496	1993	1658
B	21,916	15,289	12,720	*B*	2374	943	784
C	1844	4418	3675	*C*	1652	658	547
D	1696	3256	2707	*D*	1470	397	330
E	1200	2085	1735	*E*	1094	263	219
F	464	1052	875	*F*	650	236	196

(1) In both series the solubility falls as the CaO rises. For equivalent CaO content the glass containing the less alkaline oxide is the less soluble.

(2) The value of CaO in decreasing solubility is again emphasised, as is the effect of alkaline oxides in causing solubility. Thus glass 169 *F*, containing 27·43 per cent. of alkaline oxide, is more soluble than glass 170 *B* containing 19·16 per cent., although the former contains 19·65 per cent. of CaO and the latter only 6·88 per cent.

(3) In the first series there is undoubted evidence of reaction having taken place between the water and the powdered glass, because in several of the glasses the weight of alkaline oxides dissolved is greater than the weight given in the "weight dissolved" column. Hence the last-named must really represent "glass dissolved," less new insoluble compounds formed.

5. *Durability.*

(1) Judged by the solubility numbers given under the heading "milligrams H_2SO_4 per 100 grams," the weathering properties of the glasses of both series improve with increasing CaO content, and in contrasting the two series the glass containing the least alkaline oxides is the more durable, the molecular CaO content being the same.

(2) Classifying the glasses under the standard of durability worked out previously,* it will be seen that none of the first series of glasses fall within the standards of optical durability.

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* See Part II., p. 39.

In the second series all the glasses except the first could be used optically. The glasses 170 *B* and 170 *C* are Class 5 and Class 4 respectively. The remaining three glasses fall within Class 2. Of these three, however, only 170 *D* could be made without a tendency to devitrification.

(3) The exposure test of weathering was carried out. Table XII gives the results.

Table XII.

No.	Exposed 100 hours to air saturated with moisture at 18°.	Exposed one year to ordinary air (closed room).
	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	
169 *A*	Surface covered with patches of oily liquid.	Dull opaque skin.
B	Covered with large spots of liquid.	Dull semi-transparent film.
C	Covered with large spots of liquid.	Filmed over.
D	Covered with small spots of liquid.	do.
E	Greasy.	do.
F	Greasy (but very slight).	do.
	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	
170 *A*	Greasy.	Slight film.
B	Surface unaffected.	Very slight film.
C	do.	Unaffected.
D	do.	do.
E	do.	do.
F	do.	do.

These results bear out those of the solubility test.

Summary and General Conclusions.

(1) Glasses of the types $100SiO_2,20Na_2O,20K_2O,xCaO$ and $100SiO_2,10Na_2O,10K_2O,xCaO$ have been investigated. In each series the molecular soda–potash–silica content is the same, the only variant being the molecular CaO content.

(2) The *Density* of the glasses increases with an increase of either CaO or Na_2O,K_2O.

(3) The increase in density per molecule added is not a constant. It is greatest when the Na_2O,K_2O is least.

(4) Density in these types of glasses is additive in character, but since equal additions of CaO or Na_2O,K_2O do not result in equal increases of density, the relation is not a simple one, being modified by the constitution of the glass.

(5) The *Refractive Indices* for the *C*, *D*, and *F* lines have been found. The refractive index increases with the addition of both

CaO and Na_2O,K_2O, the first-named oxide having the greater effect upon index per molecule.

(6) Of the three lines measured, the rate of increase of refractive index is greatest for the F line and least for the C line.

(7) Where the molecular lime–silica content is the same, the glass with the higher alkaline oxide content has the higher refractive index.

(8) The refractive index increases with the density, and like density is additive in nature. Since equal additions of CaO and Na_2O,K_2O do not result in equal increases of index, the additive character of the property is modified by constitutive influences.

(9) The *Total Dispersion* increases with the addition of either CaO or Na_2O,K_2O. The rate of increase is greater in the series containing the lesser amount of Na_2O,K_2O.

(10) The ν *values* are higher in the series containing the lesser Na_2O,K_2O, and decrease as the CaO or Na_2O,K_2O content increases.

(11) These ν values continually decrease as the refractive index increases.

(12) Both ends of the spectrum lengthen as the CaO increases, and the lengthening effect is greater the less Na_2O,K_2O there is in the glass.

(13) The addition of CaO or Na_2O,K_2O causes the blue end of the spectrum to spread relatively more than the red end.

(14) The *Devitrification* of the glasses is dealt with.

(15) The *Solubility* in water of the glasses decreases with an increase in the CaO content, but increases rapidly as the amount of alkaline oxides increases.

(16) None of the glasses has a first-class durability from an optical point of view. Glasses in the vicinity of

$$100SiO_2,10Na_2O,10K_2O,20CaO,$$

if the optical constants were required ($\eta_D = 1{\cdot}525$, $\nu = 59{\cdot}4$), could be used in instruments, particularly if they could be protected. They would have a durability similar to the silicate crown No. O. 337 of Schott.

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Research Department,
Wood Bros. Glass Co., Ltd.
Barnsley.

V.—*The Development of Various Types of Glass. Part V. A Comparison of the Soda–Lime–Silica and the Potash–Lime–Silica Glasses.*

By C. J. Peddle, M.Sc.

The glasses of the above types having been treated separately,* it remains to correlate the results obtained and deal with their likenesses and differences. All these glasses can be represented by the general molecular formula $100SiO_2,xR_2O,yCaO$, where R_2O represents the oxide of sodium, the oxide of potassium, or mixtures of these two alkaline oxides. The nature of R_2O determines in no inconsiderable way the properties of the glass containing it, and there are widespread differences in the relative effects of Na_2O or K_2O in glasses of this type. The substitution of the Na_2O in glass by K_2O, whether viewed from the point of view of equal molecular proportion or equal percentage proportion by weight, does not result in a glass of exactly similar properties. In pre-war days potash compounds were largely used, to the exclusion of soda compounds, in the manufacture of the better kinds of "flint" glass, such as table ware and cut glass. During the war, owing to the scarcity and dearness of potash salts, soda salts had to be substituted in many cases, and actual manufacture has proved that the glasses containing soda differ in their properties from those containing potash. The results obtained by the author with these glasses show where and in what degree the soda and potash glasses differ in regard to the several properties which follow. The effect of the replacement of one oxide by the other is discussed in the case of each property, first from the point of view of molecular substitution, and secondly from the point of view of percentage substitution by weight. In the study of glass from the point of view of its molecular constitution, a series of glasses may be dealt with in which there is only one variant oxide. This makes for simplicity in the problem. Where the percentage constitution by weight is used as the basis of the study, complications arise when a series of like glasses is under survey, as there must be at least two variant oxides. Thus the investigation of glass problems is facilitated by following the lines of molecular constitution, but it should be augmented wherever possible by a parallel study along the lines of percentage composition. In dealing with the comparison of the effect of the substitution of one oxide for another in glass, the "dual" method of attack is, in the author's view, especially to be commended, and is used in the present paper.

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* This Journal, Trans., pp. 3, 20, 46, 59.

Table I (p. 73) shows the density of the glasses of the

$$100SiO_2,40R_2O,xCaO$$

type.

Table II (p. 73) the density of those of the $100SiO_2,20R_2O,xCaO$ type.

Fig. 1 shows the results diagrammatically.

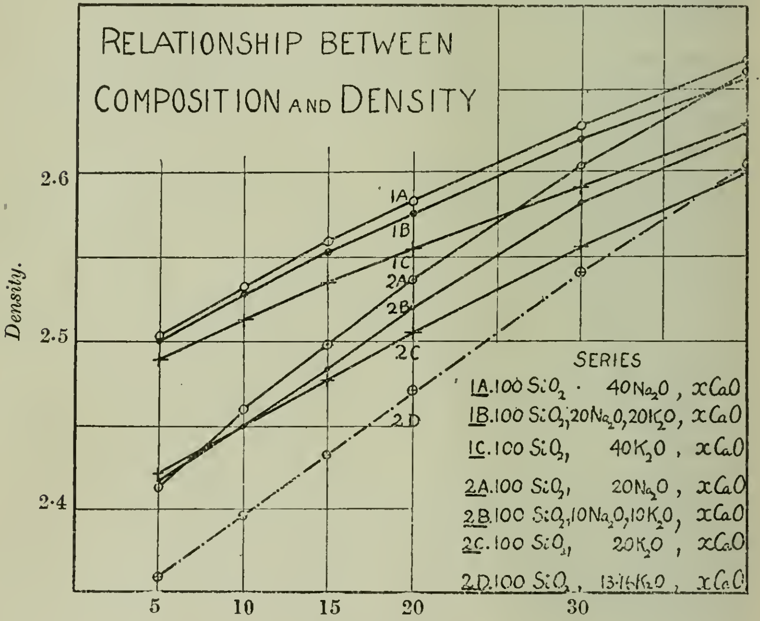

FIG. 1.

The following conclusions are to be drawn regarding the molecular substitution of K_2O for Na_2O in these glasses:—

(1) The substitution of 40 molecules of K_2O for 40 molecules of Na_2O in the series $100SiO_2,40R_2O,xCaO$ causes a fall in density.

(2) The densities of the glasses of the series

$$100SiO_2,20Na_2O,20K_2O,xCaO$$

1. *Density.*

TABLE I.

x = mols. CaO.	Series $100SiO_2,40Na_2O,xCaO$.	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	Series $100SiO_2,40K_2O,xCaO$.
5	2·503	2·502	2·488
10	2·533	2·529	2·513
15	2·559	2·554	2·535
20	2·584	2·574	2·555
30	2·629	2·619	2·594
40	2·667	2·657	2·630

TABLE II.

x = mols. CaO.	Series $100SiO_2,20Na_2O,xCaO$.	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	Series $100SiO_2,20K_2O,xCaO$.
5	2·412	2·415	2·420
10	2·458	2·450	2·450
15	2·499	2·485	2·478
20	2·537	2·523	2·505
30	2·603	2·585	2·555
40	2·659	2·626	2·601

lie between those of the $100SiO_2,40Na_2O,x$CaO and

$$100SiO_2,40K_2O,xCaO$$

series, but not midway, being nearer the soda series.

(3) In the series $100SiO_2,20R_2O,x$CaO, where x is greater than 7 molecules, the substitution of 20 molecules of Na_2O by 20 molecules of K_2O results in a fall in density.

(4) The densities of the glasses of the series

$$100SiO_2,10Na_2O,10K_2O,xCaO$$

fall between those of the $100SiO_2,20Na_2O,x$CaO and

$$100SiO_2,20K_2O,xCaO$$

series.

(5) In all glasses of the $100SiO_2,yR_2O,x$CaO type, where R_2O represents either Na_2O or K_2O, or both, the density rises with increasing CaO content, but the rate of increase is not constant. It is greater the less the amount of alkaline oxide in the glass, and it decreases as the CaO content rises. Also the increase in density is greater per molecule CaO added in glasses containing Na_2O as contrasted with glasses containing an equal molecular proportion of K_2O, that is, Na_2O has a greater effect per molecule upon density than has K_2O.

From the foregoing, it would appear that in two glasses where the percentages of lime and silica are the same, one containing Na_2O and the other K_2O in equal percentage amount, the latter would have the lower density.

All the glasses dealt with above have been studied from the point of view of molecular composition. Thus, since the molecular weight of Na_2O is 62 and K_2O 94·2, it follows that glasses containing equal molecular proportions of the two oxides will not contain equal percentage weights. In order to test the statement in the preceding paragraph and provide some data as to the effect of equivalent percentage amounts of Na_2O and K_2O upon the density of glass, several further melts were carried out.

First of all, a series of glasses of the type

$$100SiO_2,13{\cdot}16K_2O,xCaO$$

(175 series) were melted. These correspond from a percentage composition point of view exactly with those of the

$$100SiO_2,20Na_2O,xCaO$$

series (165 series), except that the alkali oxide is K_2O in the first-named series and Na_2O in the second named.

The densities of the two series are set out side by side in Table III.

TABLE III.

Percentage Composition and Density.

SiO_2.	CaO.	Na_2O. Series 165. K_2O. Series 175.	Na_2O glass (165 series).	K_2O glass (175 series).
79·90	3·73	15·97	2·412	2·360
77·03	7·19	15·39	2·458	2·397
74·37	10·41	14·85	2·499	2·432
71·86	13·42	14·36	2·537	2·472
67·36	18·86	13·44	2·603	2·542
63·37	23·65	12·67	2·659	2·607

Curve 2 *A* on Fig. 1 shows the Na_2O series and Curve 2 *D* the K_2O series.

It will be noted that the Na_2O glass has the higher density in each case, whilst the rise in density per 1 molecule increase in CaO is approximately the same in each series.

A number of melts (Series 171) were then carried out, the batches being arranged so that the glasses could be studied from the point of view of oxide content in percentage amount by weight. Table IV (p. 76) gives the densities of glasses of the 171 series.

The first four sets of glasses all contained 70 per cent. silica, the percentage of CaO rising as the percentage of alkaline oxide fell. The fifth and sixth sets contained 65 and the last two sets 60 per cent. SiO_2.

Comparison of the glasses 171 *A*, *B*, *C*, *D*, 171 *K*, *M*, and 171 *N*, *L*, gives results of the effect of substituting CaO for Na_2O in percentage amount by weight, the SiO_2 remaining constant.

The effect upon density by substituting CaO for K_2O whilst the SiO_2 remains constant is shown by 171 *E*, *F*, *G*, *H*, 171 *P*, *R*, and 171 *S*, *Q*.

In glasses 171 *B*, *K*, *L* the Na_2O is constant, the CaO being substituted for SiO_2. The companion glasses, where K_2O remains constant, are 171 *F*, *P*, *Q*.

CaO remains constant in the glasses 171 *C*, *K*, *N*, 171 *D*, *M*, *L*, and 171 *G*, *P*, *S*, 171 *H*, *R*, *Q*. In the first-named two sets, Na_2O is substituted for SiO_2, and the second two sets, K_2O is put in and SiO_2 taken out.

The glasses 171 *T*, *V*, *W*, *X*, *Y* contain both alkaline oxides, and their place in the scheme is obvious from a study of Table IV.

TABLE IV.

		Percentage.					Difference in density due to substitution of	
Set.	Melt No.	SiO_2.	CaO..	Na_2O.	K_2O.	Density.	Half Na_2O.	Whole of Na_2O.
I.	171 *A*	70	5	25	—	2·495	—	0·065
	E	70	5	—	25	2·430		
II.	171 *B*	70	10	20	—	2·525	0·016	0·058
	W	70	10	10	10	2·509	0·042	
	F	70	10	—	20	2·467		
III.	171 *C*	70	15	15	—	2·542	0·008	0·039
	V	70	15	7½	7½	2·534	0·031	
	G	70	15	—	15	2·503		
IV.	171 *D*	70	20	10	—	2·572	0·009	0·030
	T	70	20	5	5	2·563	0·021	
	H	70	20	—	10	2·542		
V.	171 *K*	65	15	20	—	2·588	0·019	0·064
	X	65	15	10	10	2·569	0·045	
	P	65	15	—	20	2·524		
VI.	171 *M*	65	20	15	—	2·616	—	0·052
	R	65	20	—	15	2·564		
VII.	171 *N*	60	15	25	—	2·605	—	0·061
	S	60	15	—	25	2·544		
VIII.	171 *L*	60	20	20	—	2·637	0·021	0·053
	Y	60	20	10	10	2·616	0·032	
	Q	60	20	—	20	2·584		

The following points require emphasis in the study of density from the point of view of percentage composition by weight.

(1) In every case investigated (SiO_2 between 60 and 70 per cent., CaO between 5 and 20 per cent., alkaline oxide between 10 and 25 per cent.), the substitution of K_2O for Na_2O per cent. for per cent. results in a decrease in density.

(2) The second difference column in Table IV gives the fall in density in going from a Na_2O glass to its corresponding K_2O glass. It will be seen that in every case, whatever the percentage of silica, this fall in density decreases as the CaO content rises.

(3) The first difference column gives the fall in density when substituting half the percentage Na_2O by K_2O, and then the remainder. It will be noted that in every case the density of the Na_2O,K_2O glass is not midway between the Na_2O and the K_2O glasses, as might be expected, but is nearer the Na_2O glass.

(4) A comparison of the densities of the glasses 171 *A*, *B*, *C*, *D* ($SiO_2=70$ per cent.), 171 *K*, *M* ($SiO_2=65$ per cent.), and 171 *N*, *L*

($SiO_2 = 60$ per cent.) shows that the rise in density per 1 per cent. CaO added, and the corresponding 1 per cent. decrease in Na_2O, has a mean value (1 per cent. CaO – 1 per cent. Na_2O) = 0·0056. The corresponding value for the K_2O glasses is 1 per cent. CaO – 1 per cent. K_2O = 0·0077. Thus, the addition of 1 per cent. CaO in this type of glass has a greater effect in the potash glass than in the soda glass, the silica remaining constant.

Fig. 2 shows the rate of increase in density with percentage rise in CaO, the SiO_2 being constant for the Na_2O, the K_2O, and the mixed oxides series. From this diagram, the density of the glass $70SiO_2,30Na_2O$ is found to be 2·467, of the glass

$$70SiO_2,15Na_2O,15K_2O$$

2·450, and of the glass $70SiO_2,30K_2O$ 2·390.

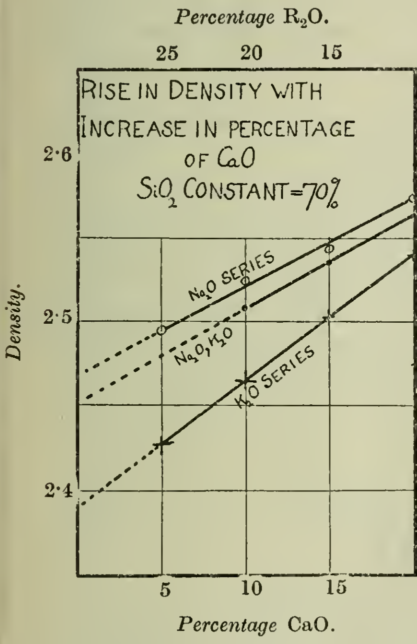

FIG. 2.

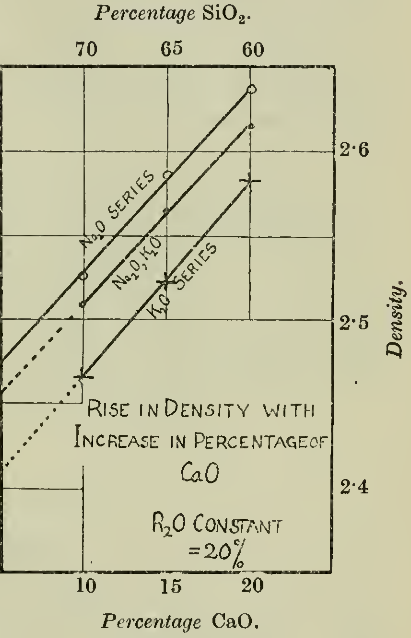

FIG. 3.

(5) When the densities of the glasses 171 *D*, *M* (CaO = 20 per cent.) and 171 *C*, *K* (CaO = 15 per cent.) are compared, a mean rise in density of 0·0088 for (1 per cent. Na_2O – 1 per cent. SiO_2) is obtained. The corresponding rise for 1 per cent. K_2O – 1 per cent. SiO_2 is 0·0042. From this it follows that when the percentage

CaO in a glass is kept constant, a rise of 1 per cent. in Na_2O increases the density more than a rise of 1 per cent. K_2O.

(6) Comparing the glasses 171 *B*, *K* ($Na_2O = 20$ per cent.) and 171 *C*, *M* ($Na_2O = 15$ per cent.), it will be seen that there is a mean rise in density of 0·0142 for 1 per cent. CaO − 1 per cent. SiO_2. The rise for 1 per cent. CaO − 1 per cent. SiO_2 in the corresponding K_2O glasses is 0·0119.

Fig. 3 shows diagrammatically the rise in density due to a rise in percentage CaO, coupled with a corresponding fall in silica, the alkali oxide being constant. It will be noted by comparing Figs. 2 and 3 that the rate of increase of density with increasing CaO percentage is greater where the alkali oxide remains constant than where the silica remains constant.

(7) From the results given in the three preceding paragraphs, it follows that

+1 per cent. CaO − 0·5 per cent. Na_2O − 0·5 per cent. $SiO_2 = 0{\cdot}0094$,
+1 per cent. CaO − 0·5 per cent. K_2O − 0·5 per cent. $SiO_2 = 0{\cdot}0093$,

that is, if the percentage of CaO in a glass of the type under investigation is increased and the percentage difference is spread equally over the other constituents, then the effect upon density of adding CaO is the same whether the glass contains Na_2O or K_2O, and is about 0·009 per 1 per cent. addition of CaO.

2. *Refractive Index.*

TABLE V.

x = mols. CaO.	Refractive index for *D* line.		
	Series $100SiO_2,40Na_2O,xCaO$.	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	Series $100SiO_2,40K_2O,xCaO$.
5	1·5110	1·5115	1·5125
10	1·5189	1·5186	1·5179
15	1·5259	1·5255	1·5229
20	1·5327	1·5314	1·5277
30	1·5442	1·5428	1·5379
40	1·5540	1·5514	1·5475

x = mols. CaO.	10^5 × Total dispersion *C* to *F*.		
	Series $100SiO_2,40Na_2O,xCaO$.	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	Series $100SiO_2,40K_2O,xCaO$.
5	898	900	901
10	918	915	914
15	938	933	927
20	955	948	938
30	984	977	960
40	1010	1002	978

TABLE VI.

$x =$ mols. CaO.	Refractive index for D line.		
	Series $100SiO_2,20Na_2O,xCaO$.	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	Series $100SiO_2,20K_2O,xCaO$.
5	1·4970	1·4992	1·5011
10	1·5088	1·5086	1·5081
15	1·5192	1·5177	1·5151
20	1·5279	1·5253	1·5223
30	1·5435	1·5401	1·5355
40	1·5573	1·5528	1·5491

$x =$ mols. CaO.	10^5 × Total dispersion C to F.		
	Series $100SiO_2,20Na_2O,xCaO$.	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	Series $100SiO_2,20K_2O,xCaO$.
5	815	823	828
10	841	843	846
15	865	865	865
20	888	884	883
30	934	928	922
40	980	966	958

Table V (p. 78) shows the refractive index of the D line and the total dispersion $(F-C)$ for glasses of the three series:—

(1) $100SiO_2,40Na_2O,xCaO$;
(2) $100SiO_2,20Na_2O,20K_2O,xCaO$; (3) $100SiO_2,40K_2O,xCaO$.

Table VI summarises the corresponding results for the glasses of the three series:—(1) $100SiO_2,20Na_2O,xCaO$;
(2) $100SiO_2,10Na_2O,10K_2O,xCaO$;
(3) $100SiO_2,20K_2O,xCaO$.

From these results, conclusions as under can be drawn as to the relative effects of Na_2O and K_2O from a molecular point of view upon the refractive indices of glasses of these types.

The results for refractive index are shown on Fig. 4, and those for total dispersion on Fig. 5.

(1) In all the above glasses, which can be represented by the general molecular formula $100SiO_2,yR_2O,xCaO$, where y is between 20 and 40 molecules of alkali oxide and x between 5 and 40 molecules of lime, increasing the CaO constant increases both the refractive index and the total dispersion. The rate of increase falls off as the molecular CaO content rises. This rate of increase is greater in the Na_2O series than in the corresponding K_2O series. In glasses containing both Na_2O and K_2O, the rate of increase is intermediate between the rates of increase in the Na_2O and K_2O series.

This statement is probably true for all values of y and x capable of yielding glasses.

(2) In every case, the refractive index and total dispersion of the glass containing half its molecular oxide content as Na_2O and half as K_2O are intermediate between the refractive index and total dispersion of the corresponding glasses containing only Na_2O and K_2O respectively. The values are not midway, but tend to be nearer the Na_2O glass. This is particularly the case in glasses containing the higher amount (40 molecules) of alkali oxides.

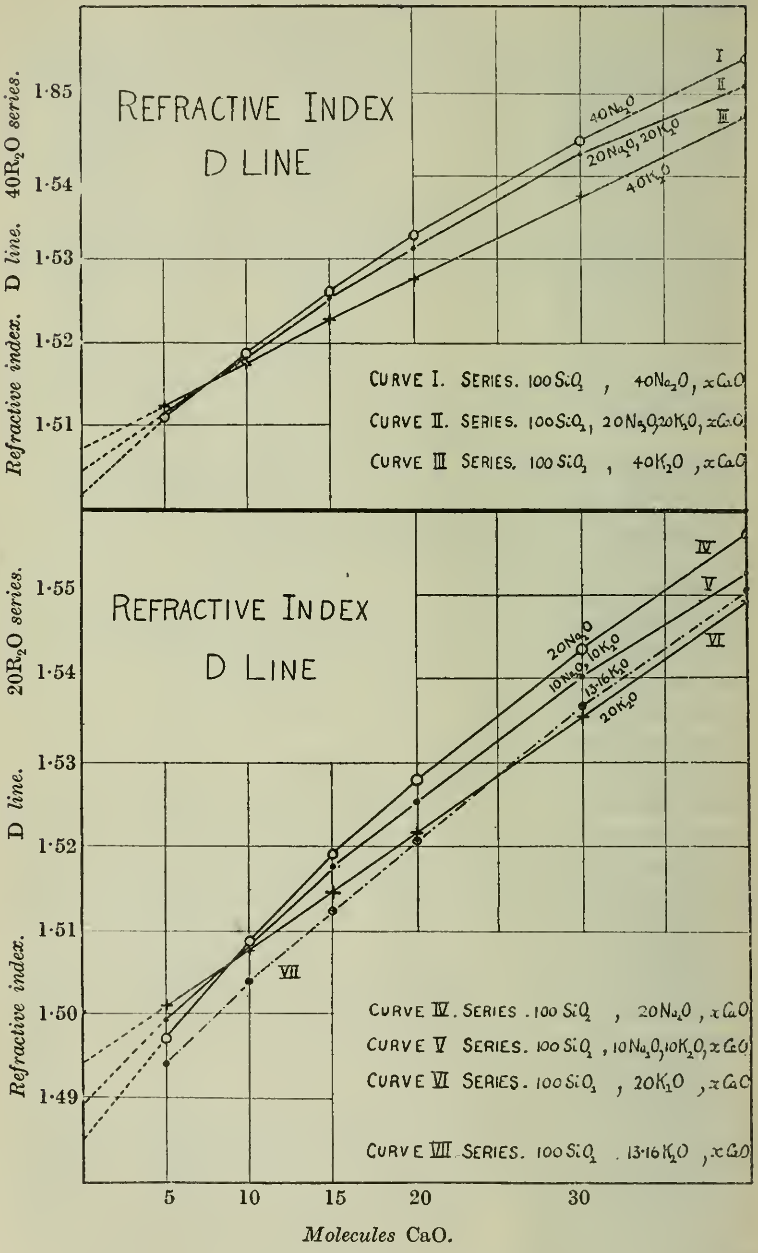
REFRACTIVE INDEX
D LINE
Refractive index. D line. 40R$_2$O series.
1·85
1·54
1·53
1·52
1·51
I
II
III
40Na$_2$O
20Na$_2$O, 20K$_2$O
40K$_2$O
CURVE I. SERIES. 100SiO$_2$, 40Na$_2$O, xCaO
CURVE II. SERIES. 100SiO$_2$, 20Na$_2$O 20K$_2$O, xCaO
CURVE III SERIES. 100 SiO$_2$, 40K$_2$O, xCaO
REFRACTIVE INDEX
D LINE
Refractive index. D line. 20R$_2$O series.
1·55
1·54
1·53
1·52
1·51
1·50
1·49
IV
V
VI
VII
20Na$_2$O
10Na$_2$O, 10K$_2$O
13·16K$_2$O
20K$_2$O
CURVE IV. SERIES. 100 SiO$_2$, 20Na$_2$O, xCaO
CURVE V SERIES. 100 SiO$_2$, 10Na$_2$O, 10K$_2$O, xCaO
CURVE VI SERIES. 100 SiO$_2$, 20K$_2$O, xCaO
CURVE VII SERIES. 100 SiO$_2$ 13·16K$_2$O, xCaO
5
10
15
20
30
Molecules CaO.

FIG. 4.

(3) In the series $100SiO_2,40R_2O,xCaO$, where the molecular CaO value is greater than 7·5, the Na_2O glass has a higher refractive index for the *D* line than the corresponding K_2O glass. From Fig. 4 (p. 80) it will be seen that the three glasses $100SiO_2,40Na_2O,7{\cdot}5CaO$, $100SiO_2,20Na_2O,20K_2O,7{\cdot}5CaO$, and $100SiO_2,40K_2O,7{\cdot}5CaO$ have the same refractive index for the *D* line, namely, 1·5150.

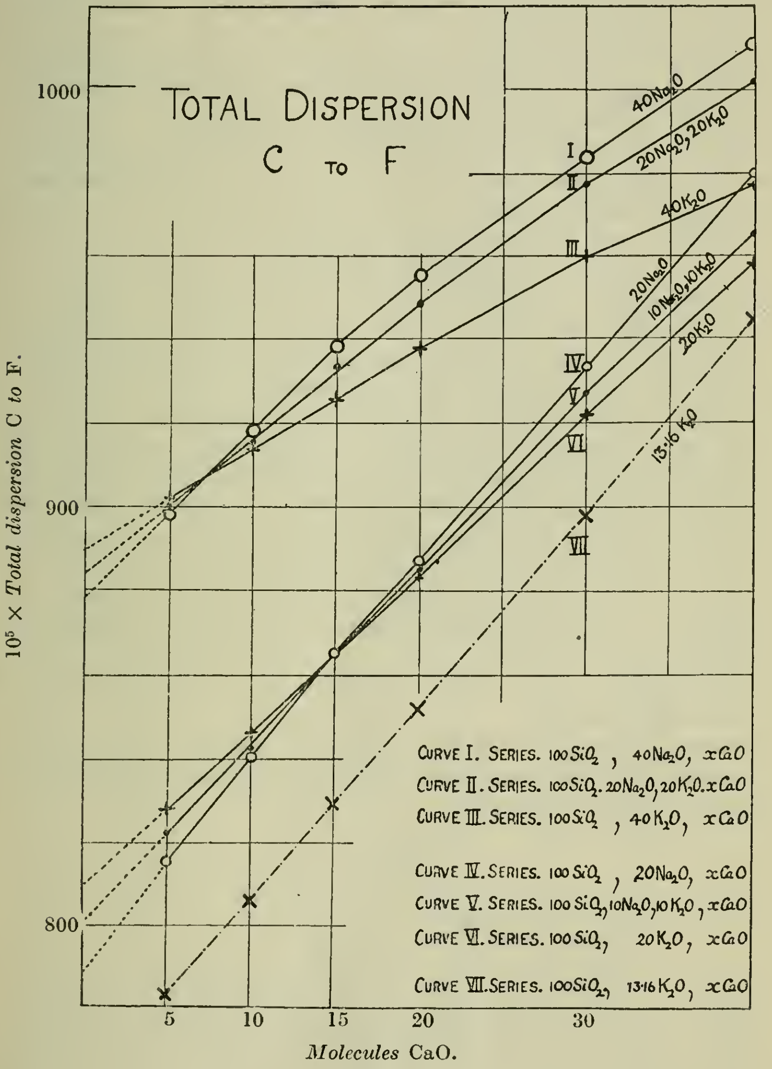

FIG. 5.

(4) In the series $100SiO_2,20R_2O,xCaO$, the Na_2O glass has the higher value when CaO is greater than 9 molecules. Thus, the three glasses $100SiO_2,20Na_2O,9CaO$, $100SiO_2,10Na_2O,10K_2O,9CaO$, and $100SiO_2,20K_2O,9CaO$ have the same refractive index for the *D* line, namely, 1·5065.

(5) In the series $100SiO_2,40R_2O,xCaO$, the total dispersion of the Na_2O glass is higher than that of the corresponding K_2O glass when the CaO content is greater than 7 molecules.

(6) In the series $100SiO_2,20R_2O,xCaO$, the total dispersion of the Na_2O glass becomes higher than that of the K_2O glass when the CaO content is larger than 15 molecules.

(7) The total dispersion of all the glasses of the type

$$100SiO_2,yR_2O,xCaO$$

increases as the refractive index of the *D* line increases, that is, the ν value falls as the refractive index of the *D* line increases.

The relative effects of Na_2O and K_2O upon the refractive index having been examined from a molecular point of view, it is necessary to discuss their relationship from the point of view of equivalent percentage by weight. The following were the results obtained with the series $100SiO_2,13·16K_2O,xCaO$ (175 series). As was pointed out under density, this series corresponds exactly with Series 165 from a percentage-weight point of view, the alkali being Na_2O in the last-named series and K_2O in the first named.

The results are set out under the headings of:—(1) refractive index for *D* line, (2) total dispersion $F-C$, (3) ν value, and (4) β value.

Alongside the results for the K_2O series are set out the results for the Na_2O series.

Curves IV and VII on Fig. 4 show the refractive indices of the two series (*D* line) diagrammatically, and Curves IV and VII on Fig. 5 the total dispersions.

TABLE VII.

Percentage Composition and Optical Constants.

		Na_2O. (165)	Refractive index, *D* line.		Total dispersion × 10^5.		ν value.		β.	
SiO_2.	CaO.	K_2O. (175).	Na_2O series.	K_2O series.	Na_2O.	K_2O.	Na_2O.	K_2O.	Na_2O.	K_2O.
79·90	3·73	15·97	1·4970	1·4943	815	783	61·98	63·13	0·700	0·699
77·03	7·19	15·39	1·5088	1·5036	841	806	60·50	62·48	0·701	0·700
74·37	10·41	14·85	1·5192	1·5127	865	829	60·03	61·83	0·702	0·701
71·86	13·42	14·36	1·5279	1·5211	888	852	59·44	61·16	0·703	0·702
67·36	18·86	13·44	1·5435	1·5371	934	898	58·20	59·81	0·705	0·705
63·37	23·65	12·67	1·5573	1·5508	980	945	58·87	58·29	0·707	0·707

It will be noted that in these two comparison series the Na_2O glass in every case has the higher refractive index for the *D* line and also the higher total dispersion. Hence, weight for weight, Na_2O has a greater effect upon refractive index than has K_2O.

The refractive indices of the glasses of the 171 series were found. This series, as explained under density (p. 75), was composed of glasses varying from one another in the percentage amount of two of their oxides, one oxide being kept constant. Thus, the glasses 171 *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, *W*, *V*, *T* were melted from batches so arranged as to give 70 per cent. SiO_2 in the final glass, the CaO varying from 5 to 20 per cent. and the alkali oxide from 25 to 10 per cent. The glasses 171 *K*, *P*, *M*, *R*, *X* had a constant SiO_2 percentage of 65, the CaO varying from 15 to 20 per cent., and the alkali oxide from 20 to 15 per cent., whilst the glasses 171 *L*, *N*, *Q*, *S*, *Y* contained a constant amount of SiO_2 of 60 per cent., the CaO varying from 15 to 20 per cent. and the Na_2O from 25 to 20 per cent.

Table VIII shows the results for the refractive indices of the 171 series, the refractive index for the *D* line, the total dispersion, the ν value, the partial dispersions (*C* to *D* and *D* to *F*), and the β value all being given. In the last column of the table, under the heading "Difference," is the difference between the refractive index of the *D* line for the Na_2O glass and its corresponding K_2O glass.

TABLE VIII.

Melt* No.	Refractive index for *D* line.	Total dispersion, $(F-C)\times10^5$.	ν.	Partial dispersion.		β.	Difference.
				$10^5(D-C)$.	$10^5(F-D)$.		
171 *A*	1·5128	896	57·24	268	628	0·701	0·0056
E	1·5072	839	60·45	251	588	0·701	
171 *B*	1·5231	905	57·81	269	636	0·703	0·0056
W	1·5206	876	59·43	260	616	0·703	
F	1·5175	852	60·74	253	599	0·703	
171 *C*	1·5330	914	58·32	271	643	0·704	0·0050
V	1·5307	882	60·17	261	621	0·704	
G	1·5280	865	61·03	256	609	0·704	
171 *D*	1·5423	923	58·75	272	651	0·705	0·0038
T	1·5406	888	60·88	262	626	0·705	
H	1·5385	878	61·30	259	619	0·705	
171 *K*	1·5367	948	56·61	281	667	0·704	0·0071
X	1·5349	918	58·26	272	646	0·704	
P	1·5296	900	58·84	266	634	0·704	
171 *M*	1·5473	957	57·19	282	675	0·705	0·0063
R	1·5410	913	59·25	269	644	0·705	
171 *N*	1·5402	982	55·01	289	693	0·706	0·0082
S	1·5320	935	56·89	275	660	0·706	
171 *L*	1·5508	990	55·63	290	700	0·707	0·0076
Y	1·5485	962	57·02	282	680	0·707	
Q	1·5432	948	57·30	279	669	0·706	

* For compositions, see Table IV., p. 76.

The following points stand out for comment:—

(1) In every case the refractive index and the total dispersion are greater in the Na_2O glass than in the corresponding K_2O glass. From the "difference" column in Table VIII it will be seen that in a series of glasses where the silica remains a constant percentage, the difference in η_D between the Na_2O glass and its corresponding K_2O glass becomes less as the CaO content becomes greater. Similarly, it will be noted that where the CaO remains constant, the difference becomes less as the SiO_2 percentage increases. Thus, in a glass of the type $a SiO_2, b CaO, c R_2O$, where $(a+b+c)=100$ per cent., the greater the value of c the greater will be the difference in refractive index between the Na_2O and K_2O glasses when either a or b is constant.

(2) From the above it will be seen that the difference between the refractive index for the D line for a Na_2O glass and its corresponding K_2O glass is not a constant, but varies according to the percentage SiO_2 and CaO in the glass. Thus, the glass

$$70SiO_2,20CaO,10Na_2O$$

has a η_D value 0·0038 higher than $70SiO_2,20CaO,10K_2O$, whilst the glass $60SiO_2,20CaO,20Na_2O$ has its η_D value 0·0076 higher than the corresponding K_2O glass.

(3) The difference in total dispersion between a Na_2O glass and its corresponding K_2O glass is more nearly a constant value. In the two sets of corresponding glasses quoted in paragraph (2), the difference in total dispersion of the first set is 0·00045 and of the second set 0·00042.

(4) Fig. 6 (p. 85) shows diagrammatically the rise in refractive index as the percentage CaO increases and the percentage of alkali oxides decreases, the silica remaining constant. It will be seen that the rate of increase for $(+1\%CaO-1\%R_2O)$ is practically the same whether R_2O is represented by Na_2O,K_2O or equal proportions of the two oxides by weight. Fig. 7 (p. 85) shows the increase in total dispersion in the same series. It will be noted that the rate of increase is greater in the K_2O than in the Na_2O series and least in the mixed series.

(5) A study of the glasses 171 *A*, *B*, *C*, *D*, 171 *K*, *M*, and 171 *N*, *L* shows that the rise in refractive index of the *D* line for

$$(+1\%CaO-1\%Na_2O)=0{\cdot}00203.$$

The increase in total dispersion for $(+1\%CaO-1\%Na_2O)=$ 0·000018.

From the corresponding K_2O glasses 171 *E*, *F*, *G*, *H*, 171 *P*, *R*, and 171 *S*, *Q* it will be found that values are as follows:—

Increase in η_D for $(+1\%CaO-1\%K_2O)=0{\cdot}00216$
Increase in total dispersion $=0{\cdot}000026$

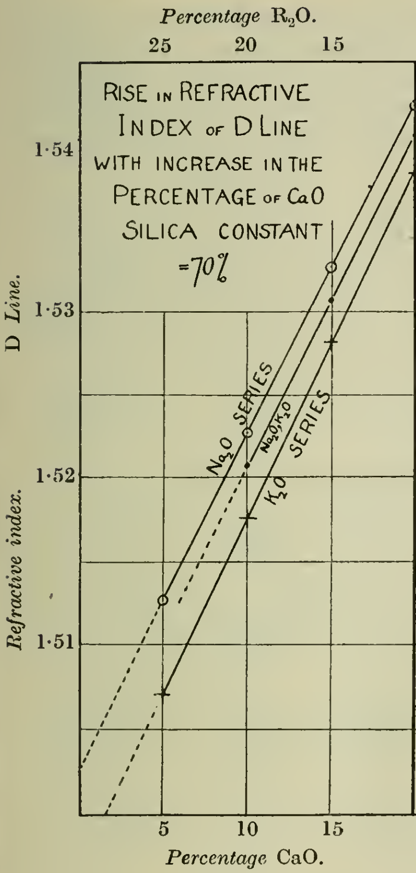

FIG. 6.

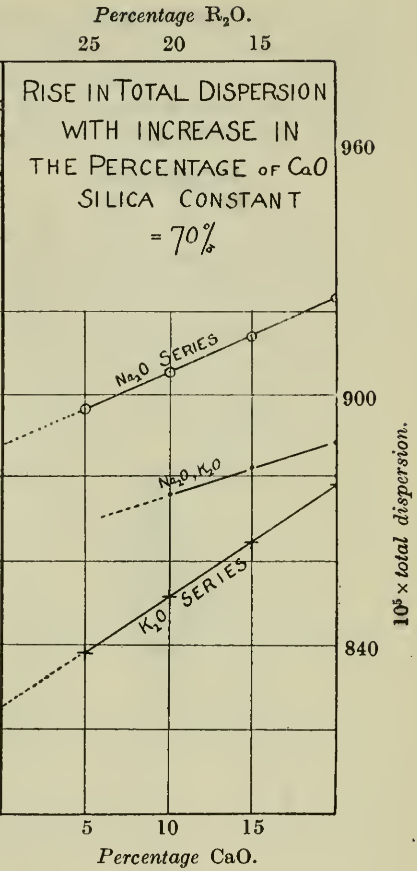

FIG. 7.

(6) The rise in refractive index, due to increasing CaO and diminishing SiO_2, the alkali oxide being kept constant, is shown in Fig. 8, whilst the rise in total dispersion is shown in Fig. 9 (p. 86). It will be seen that the rate of increase per ($+1\%CaO - 1\%SiO_2$) is approximately the same for both the Na_2O and K_2O glasses, and also for the glasses containing both the oxides.

Examination of glasses 171 *B*, *K*, *L*, 171 *F*, *P*, *Q*, and 171 *W*, *X*, *Y* gives the following values:—

Na_2O series: ($+1\%CaO - 1\%SiO_2$) $= +0·00277$ = rise in η_D
$= +0·000085$ = rise in $(F-C)$
K_2O series: ($+1\%CaO - 1\%SiO_2$) $= +0·00257$ = rise in η_D
$= +0·000096$ = rise in $(F-C)$
Na_2O,K_2O series: ($+1\%CaO - 1\%SiO_2$) $= +0·00282$ = rise in η_D
$= +0·000086$ = rise in $(F-C)$.

(7) A comparison of the numbers obtained in (5) and (6) shows that when 1 per cent. CaO is introduced into a glass of this type and 1 per cent. SiO_2 taken out to compensate, the rise in refractive index and total dispersion is greater than if 1 per cent. of alkali oxide were subtracted to compensate. This emphasises the point that it is impossible to say what will be the effect of the addition of 1 per cent. CaO unless it is specified how the remaining oxides in the glass are altered.

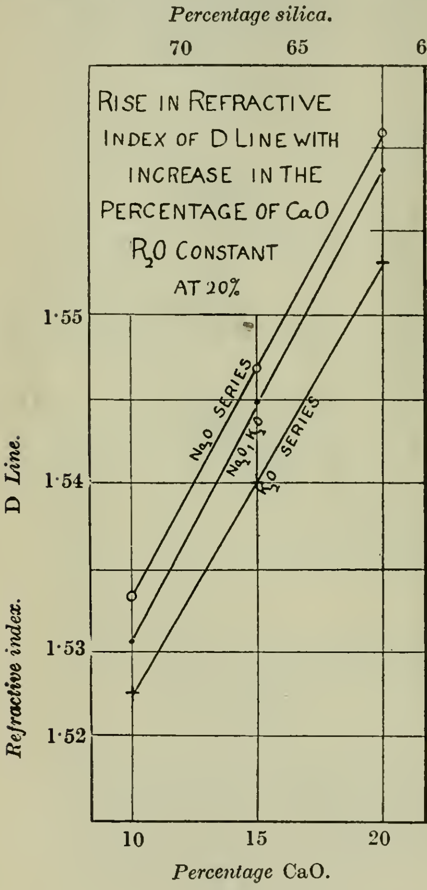

FIG. 8.

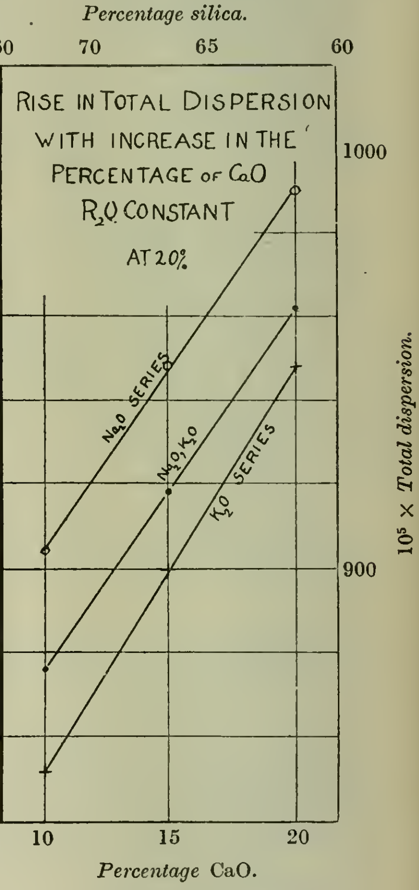

FIG. 9.

(8) From the numbers in (5) and (6) it follows that

$$+(1\%CaO - \tfrac{1}{2}\%Na_2O - \tfrac{1}{2}\%SiO_2) = +0{\cdot}00240(\eta_D) \text{ and } +0{\cdot}000052(F-C)$$

$$+(1\%CaO - \tfrac{1}{2}\%K_2O - \tfrac{1}{2}\%SiO_2) = +0{\cdot}00237(\eta_D) \text{ and } +0{\cdot}000061(F-C),$$

that is, if in glasses of the $a\mathrm{SiO}_2, b\mathrm{CaO}, c\mathrm{R}_2\mathrm{O}$ type, where $(a+b+c)=100$ per cent., b is increased to $(b+1)$ per cent., the rise in refractive index is the same whether R_2O is represented by Na_2O or K_2O, granted that the percentage difference is spread equally over the other two constituents. This rise in η_D is 0·0024.

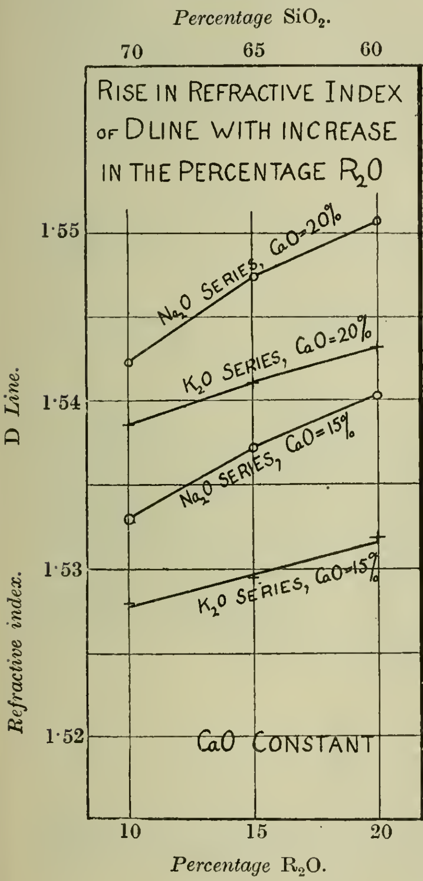

FIG. 10.

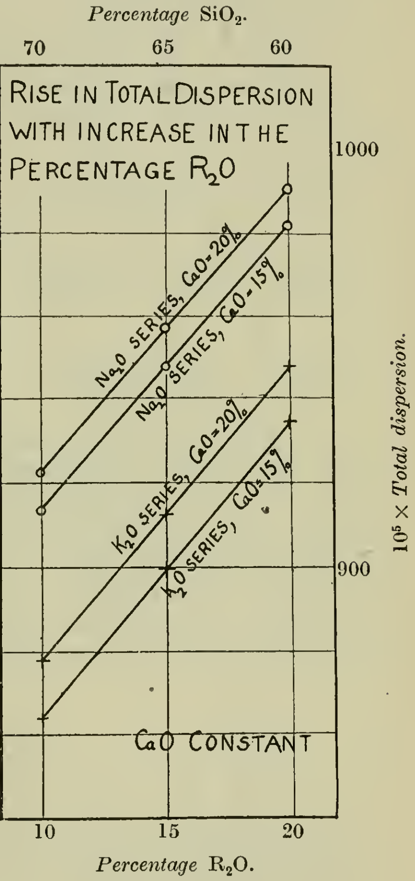

FIG. 11.

The rise in total dispersion is 0·00005 when the glass contains Na_2O and 0·00006 when K_2O is the alkali oxide.

(9) Fig. 10 shows diagrammatically the increase in η_D due to increasing the alkali oxide, the CaO being the constant oxide. Two sets are shown, one in which the glasses contain 15 per cent. CaO and the other 20 per cent. CaO. It will be noted that the increase $(+1\%Na_2O-1\%SiO_2)$ is greater than $(1\%K_2O-1\%SiO_2)$.

Fig. 11 shows the total dispersions of these glasses. It will be seen that the rate of increase is the same for both the Na_2O and K_2O glasses.

The results for the glasses 171 *D*, *M*, *L* and 171 *C*, *K*, *N* give the following values:—

$$(+1\%Na_2O-1\%SiO_2)=+0{\cdot}00078(\eta_D) \text{ and } +0{\cdot}000067(F-C).$$

The results for 171 *H*, *R*, *Q* and 171 *G*, *P*, *S* give the values:—

$$(+1\%K_2O-1\%SiO_2)=+0{\cdot}00043(\eta_D) \text{ and } +0{\cdot}000070(F-C).$$

(10) From the numbers in (5) and (9) it follows that

$$+1\%Na_2O-\tfrac{1}{2}\%CaO-\tfrac{1}{2}\%SiO_2=-0{\cdot}00063(\eta_D) \text{ and } +0{\cdot}000025(F-C)$$

and

$$+1\%K_2O-\tfrac{1}{2}\%CaO-\tfrac{1}{2}\%SiO_2=-0{\cdot}00087(\eta_D) \text{ and } +0{\cdot}000022(F-C).$$

(11) Examination of the numbers in (6) and (9) yield values

$$+1\%SiO_2-\tfrac{1}{2}\%CaO-\tfrac{1}{2}\%Na_2O=-0{\cdot}00178(\eta_D) \text{ and } -0{\cdot}000076(F-C).$$

and

$$+1\%SiO_2-\tfrac{1}{2}\%CaO-\tfrac{1}{2}\%K_2O=-0{\cdot}00150(\eta_D) \text{ and } -0{\cdot}000083(F-C).$$

(12) The following statement is deduced from (8), (10), and (11). In glasses of the type $a SiO_2, b CaO, c R_2O$, where $(a+b+c)=$ 100 per cent. if the CaO is increased 1 per cent. and the difference in percentage spread over the SiO_2 and R_2O equally, both refractive index for *D* line and total dispersion are increased. Where the SiO_2 is increased 1 per cent., both η_D and $F-C$ decrease; where R_2O is increased 1 per cent., η_D decreases and $F-C$ increases, the difference being spread equally in each case.

3. *Devitrification.*

The results of the devitrification tests* for the series of glasses $100SiO_2,40R_2O,xCaO$ are shown in Table IX, those for the series $100SiO_2,20R_2O,xCaO$ in Table X (p. 88).

From these results are to be drawn the following conclusions:—

Series $100SiO_2,40R_2O,xCaO$.

(1) The glasses containing 40 molecules of K_2O have a tendency to devitrify when the CaO content is less than 20 molecules. The substance separating is probably potassium silicate. The corresponding Na_2O glasses show no tendency to separate sodium silicate.

(2) None of the glasses show evidence of any SiO_2 separation.

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* This Journal, Trans., pp. 34, 55, 65.

TABLE IX.

	Series $100SiO_2,40Na_2O,xCaO$.		Series $100SiO_2,20Na_2O,20K_2O,xCaO$.		Series $100SiO_2,40K_2O,xCaO$.	
Mols. CaO.	Melt No.	Result.	Melt No.	Result.	Melt No.	Result.
5	163 *A*	No devitrification.	169 *A*	No devitrification.	167 *A*	Devitrifies (K silicate).
10	*B*	do.	*B*	do.	*B*	do.
15	*C*	do.	*C*	Very slight devitrification.	*C*	do.
20	*D*	Devitrifies (Ca silicate).	*D*	Devitrifies (Ca silicate).	*D*	Partial devitrification.
30	*E*	do.	*E*	do.	*E*	No devitrification.
40	*F*	do.	*F*	do.	*F*	do.

TABLE X.

	Series $100SiO_2,20Na_2O,xCaO$.		Series $100SiO_2,10Na_2O,10K_2O,xCaO$.		Series $100SiO_2,20K_2O,xCaO$.	
Mols. CaO.	Melt No.	Result.	Melt No.	Result.	Melt No.	Result.
5	165 *A*	Devitrifies (silica).	170 *A*	No devitrification.	168 *A*	No devitrification.
10	*B*	do.	*B*	do.	*B*	do.
15	*C*	Very slight devitrification.	*C*	do.	*C*	do.
20	*D*	No devitrification.	*D*	do.	*D*	do.
30	*E*	Devitrifies (Ca silicate).	*E*	Devitrifies (Ca silicate).	*E*	do.
40	*F*	do.	*F*	do.	*F*	Devitrifies (Ca silicate).

(3) Where the molecular CaO content is greater than 15 molecules, calcium silicate tends to separate out in the Na_2O series, but not in the K_2O series.

(4) The glasses of the $100SiO_2,20Na_2O,20K_2O,xCaO$ series have devitrification properties intermediate between those of the corresponding Na_2O and K_2O series, but approach the Na_2O series.

Series $100SiO_2,20R_2O,xCaO$.

(1) Only the glasses of the $20Na_2O$ series show signs of silica separation, and then only when the CaO content is less than 15 molecules.

(2) In the $20Na_2O$ series and the $10Na_2O,10K_2O$ series, a molecular content of 30 or more CaO causes calcium silicate devitrification. The glass containing 30 molecules CaO in the K_2O series does not devitrify, but the 40 molecules CaO glass does.

(3) The devitrification properties of the

$$100SiO_2,10Na_2O,10K_2O,xCaO$$

series are intermediate between those of the Na_2O and K_2O series, but approach nearer the Na_2O series.

All these results point to the fact that, molecule for molecule, Na_2O is more powerful in inducing devitrification than K_2O. It should be borne in mind that this is in spite of the fact, that the K_2O in each pair of glasses compared, is in a greater proportion by weight. Since tendency to devitrification will be enhanced by the greater fluidity of the glass at its devitrification point, enabling crystal nuclei to form and grow, it might be expected that the K_2O glasses would show most devitrification tendencies. Since they do not, it must be inferred that the Na_2O glass is more fluid than the corresponding K_2O glass at the temperature used (900°). From this it follows that, molecule for molecule, Na_2O must be a better flux than K_2O, and a much better flux regarded from a weight for weight point of view.

In order to test this point and increase data upon devitrification in this type of glass, pieces of melts 175 and 171 (see density and refractive index) were subjected to the previously described tests for devitrification.

As previously pointed out, the glasses of Series 175 are identical in percentage composition with those of 165 series, except they contain K_2O for Na_2O. The devitrification results for the two series are shown in Table XI below, and some data as to their melting properties.

TABLE XI.

Percentage Composition and Devitrification.

		Na_2O or	Melting properties.		Devitrification.	
SiO_2.	CaO.	K_2O.	Na_2O series.	K_2O series.	Na_2O series.	K_2O series.
79·90	3·73	15·97	Not melted.	Not melted.	Devitrifies (silica).	Slight devitrification (SiO_2).
77·03	7·19	15·39	do.	do.	Devitrifies (silica).	No devitrification.
74·37	10·41	14·85	Melted.	do.	Devitrifies (silica).	No devitrification.
71·86	13·42	14·36	do.	do.	No devitrification.	No devitrification.
67·36	18·86	13·44	do.	do.	Devitrifies (Ca silicate).	No devitrification.
63·37	23·65	12·67	Not melted.	do.	Devitrifies (Ca silicate).	No devitrification.

Regarding the term "melting properties," when the rough-shaped piece of glass completely flowed down and entirely filled the container, it was regarded as melted. When it preserved its original shape it was regarded as not melted, although sharp edges might have been rounded off. Occasionally a piece of glass would "flow down" to some extent, but not sufficiently to fill the container. It was then termed "partially melted."

The evidence from the above table is conclusive that the Na_2O glasses flow down at a lower temperature than their corresponding K_2O glasses. This evidence serves to support that observed during the melting of the two series. The K_2O glasses were more difficult to "found" than the Na_2O glasses, and on examination, after the same furnace treatment, they were inclined to be more "batchy," more seedy, more cordy, and more irregular in fracture than the Na_2O glasses. Each of these symptoms is an indication of difficulty in founding in the alkali–lime–silicate type of glass.

The results in the 171 series are given in Table XII. From these a very comprehensive view of the relative effect of Na_2O and K_2O upon devitrification, regarded from the viewpoint of equivalent percentage by weight, may be obtained.

In the last column an attempt is made to show the order in which the glasses flow down at 900°, an estimate being made upon the appearance of the glasses after the devitrification test.

The following points require notice when the melting properties of these glasses are studied:—

(1) In every case, whatever the percentage SiO_2 or CaO content, the Na_2O glass is more easily melted than the corresponding K_2O glass, that is, weight for weight, Na_2O is a better flux than K_2O.

(2) If the percentage SiO_2 remains constant, increasing the CaO raises the melting point.

TABLE XII.

Melt* No.	Devitrification result.	Melting result.	Order of flowing down
171 *A*	Slightly devitrifies (silica) .	Melted	1
E	No devitrification	do.	3
171 *B*	No devitrification...........	Melted.	2
W	do.	Not melted.	12
F	do.	do.	19
171 *C*	Surface devitrification	Part melted.	9
V	No devitrification...........	Not melted.	14
G	do.	do.	19
171 *D*	Devitrifies	Not melted.	14
T	No devitrification	do.	16
H	do.	do.	18
171 *K*	Devitrifies (Ca silicate)	Melted.	3
X	do.	do.	7
P	No devitrification	Not melted.	16
171 *M*	Devitrifies	Just melted.	9
R	No devitrification	Not melted.	21
171 *N*	Devitrifies	Melted.	3
S	No devitrification	do.	6
171 *L*	Devitrifies	Just melted.	8
Y	do.	Part melted.	9
Q	No devitrification	Not melted.	12

* For compositions, see Table IV., p. 76.

(3) If the percentage CaO remains constant, increasing the SiO_2 raises the melting point.

(4) When the K_2O is greater than 25 per cent., the glasses between 60 and 70 per cent. SiO_2 melt down at less than 900°.

(5) When the Na_2O is greater than 20 per cent., the glasses with 60 to 70 per cent. SiO_2 melt down at less than 900°.

(6) Where the alkali content is composed of equal percentage amounts by weight of Na_2O and K_2O, the melting is intermediate between that of the Na_2O and K_2O glasses, tending to be nearer the Na_2O glass.

Considering now the general results, the following observations have to be made:—

(1) In every case, devitrification under the conditions named is more marked with the Na_2O glass than with the K_2O glass; in fact, not a single K_2O glass devitrified, although some contained as high a percentage of CaO as 20. The tendency of the Na_2O glass to devitrify is particularly striking in glasses where the SiO_2 falls below 70 per cent. Here a soda glass containing more than 15 per cent. CaO on prolonged heating at 900° was converted into a white

porcelain mass, whilst the K_2O glass was entirely unaffected. In the case of the two glasses $65SiO_2,15CaO,20K_2O$ and

$$60SiO_2,20CaO,20K_2O,$$

which do not develop devitrification, substitution of half the percentage of K_2O by Na_2O causes devitrification.

(2) In a series of Na_2O glasses, where the SiO_2 remains constant, there is an increasing tendency to devitrification as the percentage of CaO increases.

(3) In a series of Na_2O glasses, where the CaO remains constant, the addition of SiO_2 tends to decrease devitrification as long as its percentage does not rise above 70.

(4) In certain circumstances, where the SiO_2 content is high, an increase in CaO will tend to prevent silica devitrification (see melts 171 *A* and *B*).

The above results serve to emphasise the fact that fluidity plays a part in the phenomenon of devitrification. As previously stated, the less viscous a glass is, the better chance will nuclei have to grow. Comparison of the last three columns in Table XII show this very well. They also indicate the second factor upon which devitrification depends, namely, composition of the glass. The third important factor is temperature. In all probability, the K_2O glasses, if raised to a higher temperature than 900° until molten and held there, would exhibit devitrification. Thus the above results are only comparative for the particular condition under which the tests were carried out.

4. *Solubility.*

As was pointed out in a previous paper,* to estimate the insoluble left after boiling the powdered glass with water, or to boil down the filtrate to dryness, does not give a true criterion of the solubility of the glass, because in some cases there is a reaction between the water and the glass, resulting in new compounds, soluble or insoluble, as the case may be. The most trustworthy and useful method in glasses of this type, where the substance dissolved out of the glass is alkali, with perhaps some alkaline silicate,† is to estimate the amount of H_2SO_4 required to neutralise the filtrate. The H_2SO_4 figure itself may be used to compare the solubilities of like glasses, as was done in previous papers. For comparison of the solubility of unlike glasses, where the alkalis are different, it is preferable to transform this figure into its equivalent of alkali, that is, in the case of glasses containing Na_2O, multiply it by 0·6327, and with K_2O multiply by 0·9623. In the case of glasses containing equal molecular proportions of K_2O and Na_2O, the conversion is not so easily carried out. The factor used in the results which follow is 0·8318, the assumption being made that the Na_2O and K_2O are dissolved out in the ratio of their equivalents, that is, 62 parts of Na_2O to every 94·3 parts of K_2O. When glasses contain equal percentage amounts of Na_2O and K_2O, it is assumed that the two oxides are dissolved out equally, the factor then becoming 0·7975.

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* Part II., p. 37.

† In these glasses it was found that the residue left behind after evaporation of the solution formed by boiling the glass with water consisted chiefly of alkaline hydrate and silicate. No calcium compound could be detected, even in the residue from glasses rich in calcium.

Table XIII sets out the solubilities of the glasses of the series $100SiO_2,40R_2O,x CaO$, and Table XIV those of the series

$$100SiO_2,20R_2O,x CaO.$$

From these two tables, in which the solubilities are expressed in terms of milligrams of alkali (R_2O) dissolved out per 100 grams of glass, several facts may be deduced as to the relative solubilities of Na_2O and K_2O glasses, built up on the "molecular basis."

Examination of the two tables of results leads to the following conclusions:—

(1) The extreme solubility of glasses with high alkali content. Thus, of the glass $100SiO_2,40Na_2O,5CaO$, more than 10 per cent. dissolves in water. The Na_2O content is 27·5 per cent., and the CaO 3·22 per cent. The corresponding K_2O glass (37·4 per cent. K_2O and 2·8 per cent. CaO) dissolves to the extent of 27 per cent. Even the glass $100SiO_2,40K_2O,15CaO$, which contains nearly 8 per cent. CaO, dissolves to the extent of 20 per cent.

(2) The value of CaO in reducing solubility is very marked.

(3) In corresponding glasses containing equal molecular proportions of Na_2O and K_2O, the potash glass has the higher solubility.

(4) The glasses containing equal molecular proportions of both Na_2O and K_2O are intermediate between the corresponding Na_2O and K_2O glasses, except $100SiO_2,10Na_2O,10K_2O,5CaO$ and

$$100SiO_2,10Na_2,10K_2O,10CaO,$$

which have a solubility less than either of their corresponding soda or potash glasses. This fact is of interest, particularly in view of the later results obtained when comparing the effect of equivalent percentage amounts of Na_2O and K_2O.

To compare the effect of equal percentage amounts of Na_2O and K_2O, the solubilities of the glasses of 175 series

$$(100SiO_2,13{\cdot}16K_2O,x CaO)$$

TABLE XIII.

	Series $100SiO_2,40Na_2O,xCaO$.		Series $100SiO_2,20Na_2O,20K_2O,xCaO$.		Series $100SiO_2,40K_2O,xCaO$.	
x = mols. CaO.	Melt No.	Milligrams Na_2O per 100 grams.	Melt No.	Milligrams Na_2O,K_2O per 100 grams.	Melt No.	Milligrams K_2O per 100 grams.
5	163 *A*	11,670	169 *A*	25,140	167 *A*	27,260
10	*B*	5664	*B*	12,720	*B*	26,560
15	*C*	2694	*C*	3675	*C*	19,590
20	*D*	2361	*D*	2707	*D*	8312
30	*E*	1444	*E*	1735	*E*	4948
40	*F*	672	*F*	875	*F*	2111

TABLE XIV.

	Series $100SiO_2,20Na_2O,xCaO$.		Series $100SiO_2,10Na_2O,10K_2O,xCaO$.		Series $100SiO_2,20K_2O,xCaO$.	
x = mols. CaO.	Melt No.	Milligrams Na_2O per 100 grams.	Melt No.	Milligrams Na_2O,K_2O per 100 grams.	Melt No.	Milligrams K_2O per 100 grams.
5	165 *A*	1915	170 *A*	1658	168 *A*	5145
10	*B*	845	*B*	784	*B*	1384
15	*C*	419	*C*	547	*C*	927
20	*D*	253	*D*	330	*D*	581
30	*E*	217	*E*	219	*E*	342
40	*F*	157	*F*	196	*F*	291

were found. These are shown in Table XV, the results for the Na_2O series corresponding in percentage ($100SiO_2,20Na_2O,xCaO$) being placed alongside for comparison.

TABLE XV.

Percentage.			Solubility in milligrams alkali per 100 grams of glass.	
SiO_2.	CaO.	Na_2O or K_2O.	Na_2O (Series 165).	K_2O (Series 175).
79·90	3·73	15·97	1915	1578
77·03	7·19	15·39	845	550
74·37	10·41	14·85	419	334
71·86	13·42	14·36	253	282
67·36	18·86	13·44	217	263
63·37	23·65	12·67	157	210

From these results it will be seen that in the first three corresponding sets of glass the soda glass is the more soluble.

In order to obtain fuller data as to the effect on solubility of the two oxides from a percentage point of view, experiments were carried out with the 171 series of glasses. The results are embodied in Table XVI, and are set out under the three headings:—(1) weight dissolved; (2) milligrams of H_2SO_4 required to neutralise the solution from 100 grams of the powdered glass; (3) milligrams of alkali equivalent to the H_2SO_4. The weight dissolved was found by subtracting the residue left after boiling from the weight of the original glass.

The glasses are arranged in the table in eight sets, as they were under density and refractive index, the glasses of the first four sets containing 70 per cent. SiO_2, those of the fifth and sixth sets 65 per cent. SiO_2, and those of the last two sets 60 per cent. SiO_2.

(1) From the point of view of "weight dissolved," in every case it would appear that the K_2O glass is more soluble than the corresponding Na_2O glass, whilst the glass containing both Na_2O and K_2O is not intermediate, but less soluble than either the corresponding Na_2O or K_2O glass.

(2) When the solubilities are judged by the numbers found under "milligrams H_2SO_4" and under "milligrams alkali," it will be seen that the Na_2O glass appears the more soluble in every case,* whilst the mixed glasses again have a solubility less than either the corresponding Na_2O or K_2O glass. That glasses containing equal percentages of the two oxides should have solubilities below either of the corresponding glasses containing only the one alkali oxide is a very striking fact. As previously pointed out (Part II, p. 37), the glasses of the Na_2O type tend to give a solubility value under "weight dissolved" lower than the true one, and therefore

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* Except in the first set under "Mg. alkali."

it is preferable to judge the relative solubility of the Na_2O and K_2O glasses by the "milligrams of alkali extracted" rather than by "weight dissolved."

(3) A study of the table as a whole shows the remarkable value of CaO in decreasing solubility. This power of CaO to reduce solubility is most marked in the Na_2O series, and is greater the smaller the amount of SiO_2 in the glass. Where the percentage of SiO_2 remains constant in a series, the effect of increasing the CaO becomes less as the percentage of CaO increases (melts 171 *A*, *B*, *C*, *D* and 171 *E*, *F*, *G*, *H*).

TABLE XVI.

Melt No.	Wt. dissolved per 100 grams.	Mg. H_2SO_4.	Mg. alkali.
171 *A*	1·840	5317	3364
E	2·732	4503	4333
171 *B*	0·952	1638	1036
W	0·772	674	538
F	2·250	749	721
171 *C*	0·688	436	276
V	0·560	223	178
G	1·306	240	231
171 *D*	0·420	292	185
T	0·370	156	124
H	0·760	173	167
171 *K*	1·196	1123	710
X	1·132	491	392
P	1·500	598	575
171 *M*	1·214	565	360
R	2·094	277	267
171 *N*	0·864	1984	1255
S	1·926	999	961
171 *L*	0·772	721	530
Y	0·504	397	317
Q	1·840	508	489

(4) A comparison of melts 171 *C*, *K*, *N*, 171 *G*, *P*, *S*, 171 *D*, *M*, *L*, 171 *H*, *R*, *Q*, shows the value of increasing the SiO_2 in a glass, the solubility decreasing with a rise in SiO_2. The less the amount of SiO_2 or CaO in a glass, the greater is the effect of increasing the SiO_2.

(5) From the results in Table XVI it is possible to compare the relative effects of CaO and SiO_2. Considering a glass containing 20 per cent. or more of alkali, if CaO is reduced and SiO_2 added in equivalent proportion by weight, its solubility is less. The higher the alkali, the greater will be the reduction in solubility

of interchanging silica for lime. On the other hand, if the glass contains 15 per cent. alkali or less, interchange of silica for lime causes the solubility to rise.

(6) In any of these glasses it can be shown that the alkali oxide governs the solubility to a far greater extent than either the lime or the silica. Thus, suppose any of these glasses, say, a very common and useful glass of percentage composition

$$70SiO_2,15CaO,15Na_2O,$$

is taken. Its solubility is represented by 276 mg. If 1 per cent. of Na_2O is added, and the percentage difference spread equally over the other two oxides, the glass $69{\cdot}5SiO_2,14{\cdot}5CaO,16Na_2O$ will have a solubility value 355 mg. Suppose, on the other hand, 1 per cent. of CaO is added and the difference spread equally. The new glass, $69{\cdot}5SiO_2,16CaO,14{\cdot}5Na_2O$, will have a value 209 mg. Thus a 1 per cent. rise in Na_2O raises the solubility 79 mg., whilst a 1 per cent. rise in CaO lowers it 65 mg. Similarly, if 1 per cent. of SiO_2 were added and the difference spread equally, the new glass, $71SiO_2,14{\cdot}5CaO,14{\cdot}5Na_2O$, would have a value 265 mg., a fall of 11 mg. The greater the amount of alkali in the glass, the more pronounced is the part played by it in determining solubility.

5. *Durability.*

The four following tables allow a comparison to be made of the two series $100SiO_2,40R_2O,x CaO$ and $100SiO_2,20R_2O,x CaO$ from the point of view of durability, first under exposure to moist air, and secondly to ordinary atmospheric conditions, polished surfaces being exposed in each case.

The results set out above lead to the following conclusions:—

(1) Where K_2O is substituted molecularly for Na_2O, the resultant glass is not so good from a weathering point of view as the original Na_2O glass.

(2) The glasses containing both Na_2O and K_2O in equivalent molecular proportions are intermediate in their weathering properties between the corresponding Na_2O and K_2O glasses.

(3) Increasing the Na_2O or K_2O in a glass lowers the durability, whilst an increase in CaO or SiO_2 improves it.

In order to get information as to the relative effects of Na_2O and K_2O upon weathering of glass from an equivalent percentage by weight viewpoint, the two series 175 and 171 were tested.

The glasses of Series 175 ($100SiO_2,13{\cdot}16K_2O,x CaO$) were identical in percentage composition with those of the 165 series

$$(100SiO_2,20Na_2O,x CaO),$$

except that the first named contained K_2O and the second Na_2O.

TABLE XVII

Test: Exposure to moist air at 18° for 100 hours.

Mols. CaO.	Series $100SiO_2,40Na_2O,xCaO$.	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	Series $100SiO_2,40K_2O,xCaO$.
5	Greasy film and drops of liquid.	Patches of oily liquid.	Pool of liquid—crinkled skin.
10	Slight greasy film.	Large spots of liquid.	Thick oily film.
15	Very slight film.	do.	Thin oily film.
20	Faint signs of film.	Small spots of liquid.	Spots of liquid.
30	No effect.	Greasy.	Faintly dimmed.
40	do.	No effect.	No effect.

TABLE XVIII.

Test: Exposure to moist air at 18° for 100 hours.

Mols. CaO.	Series $100SiO_2,20Na_2O,xCaO$.	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	Series $100SiO_2,20K_2O,xCaO$.
5	No effect.	Greasy.	Greasy.
10	do.	No effect.	No effect.
15	do.	do.	do.
20	do.	do.	do.
30	do.	do.	do.
40	do	do.	do.

TABLE XIX.

Test: Exposure to ordinary atmospheric conditions (closed room) for one year.

Mols. CaO.	Series $100SiO_2,40Na_2O,xCaO$.	Series $100SiO_2,20Na_2O,20K_2O,xCaO$.	Series $100SiO_2,40K_2O,xCaO$.
5	Dull. White, crystalline powder.	White, crystalline powder.	Thick, white, opaque skin.
10	Dull. Signs of crystals.	Dull. Signs of crystals.	Almost opaque skin.
15	do.	Semi-opaque film.	Very bad skin.
20	Dull. Surface spotted.	Film.	Bad film.
30	do.	Slight film.	Filmed over.
40	Dull in patches.	do.	Faintly filmed.

TABLE XX.

Test: Exposure to ordinary atmospheric conditions (closed room) for one year.

Mols. CaO.	Series $100SiO_2,20Na_2O,xCaO$.	Series $100SiO_2,10Na_2O,10K_2O,xCaO$.	Series $100SiO_2,20K_2O,xCaO$.
5	Dull in patches.	Faintly filmed all over.	Faintly filmed all over.
10	Slight signs of filming.	Very faint film.	Very faint film.
15	No effect.	No effect.	Very slight signs.
20	do.	do.	No effect.
30	do.	do.	do.
40	do.	do.	do.

The glasses of both series were unaffected in the moist air test. In the exposure for one year to ordinary air, the K_2O glasses were slightly superior to those of the Na_2O, but the amount of surface attack in both series was too small to judge accurately.

Series 171 yielded more certain results, which are set out in Tables XXI, XXII, and XXIII.

TABLE XXI.

$SiO_2 = 70$ per cent.*

Melt No.	100 Hours in moist air at 18°	One year in ordinary air (closed room).
171 *A*	Covered with wet spots.	Very pronounced film all over surface.
E	do.	do.
171 *B*	Very greasy.	Pronounced film all over glass.
W	Faintly greasy.	Slight film all over glass.
F	Greasy.	do.
171 *C*	Slightly greasy,	Filmed all over.
V	No effect.	Very slight film.
G	do.	do.
171 *D*	No effect.	Extremely slight film.
T	do.	Extremely slight film (less than *D*).
H	do.	do.

TABLE XXII.

$SiO_2 = 65$ per cent.*

Melt No.	100 Hours in moist air at 18°.	One year in ordinary air (closed room).
171 *K*	Slightly greasy.	Faint film.
X	No effect.	Very faint film.
P	do.	do.
171 *M*	Slightly greasy.	Faint film.
R	No effect	Very faint film.

TABLE XXIII.

$SiO_2 = 60$ per cent.*

Melt No.	100 Hours in moist air at 18°.	One year in ordinary air (closed room).
171 *N*	Slightly spotted.	Faint film.
S	No effect.	Very faint film.
171 *L*	Slightly greasy.	Faint film.
Y	No effect.	Very faint film.
Q	do.	do.

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* For full composition, see p. 76.

From the results of the first test it will be seen that the potash glass is always better for weathering than the corresponding soda glass, whilst the glass containing both Na_2O and K_2O is intermediate in its property of weathering. This test also reveals the following points:—

(1) In the glasses where the silica remains constant, increasing the lime, that is, decreasing the alkali, improves the durability.

(2) In the glasses where the lime content remains constant, increasing the silica or decreasing the alkali improves the durability.

The results obtained in the first test are borne out by the longer exposure test to ordinary air. Practically all the glasses containing soda only became filmed over, no matter what the SiO_2 or CaO content. The K_2O glasses were certainly better than the corresponding soda ones.

It will be seen that the order of durability as determined by the above two tests is very much the same as the order of solubility (see p. 97), once more bearing out the fact that for the comparison of a series of glasses as to their durability, the solubility of the powdered glass in water is of considerable use.

The weathering properties of a soda-lime–silicate glass can be improved, therefore, by increasing the percentage of either CaO or SiO_2 in the glass, and also by substituting some of the Na_2O by K_2O.

The use of Na_2O alone is to be deprecated in the making of this type of glass, and a mixture of the two alkalis or potash alone is to be recommended. To ensure good weathering, the alkali content should not rise above 15 per cent. As a matter of fact, the only glasses giving a first-class weathering number* are those containing only 10 per cent. of alkali.

6. *Pot Attack.*

(1) In every case the potash glass had less colour than the corresponding soda glass, and it was also more brilliant. At first it was thought that the K_2O glass was less coloured owing to the absorption of less pot material, and therefore less iron oxide from this material (most pot clays contain at least 2 per cent. iron oxide). The fact that the K_2O glass is more difficult to flux than its corresponding Na_2O glass seems to bear out this assumption, as under the same conditions of time and temperature the more fusible glass would be expected to exert the greater pot attack.

(2) On further investigation, however, it was found that a

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* See Part II., p. 39.

potash glass, although considerably less coloured than a like soda glass, often contained as much, if not more, iron oxide. For example, the glass $100SiO_2,40Na_2O,20CaO$, on analysis, was found to have absorbed from the pot 0·98 per cent. of Al_2O_3 and 0·10 per cent. of Fe_2O_3. The corresponding potash glass,

$$100SiO_2,40K_2O,20CaO,$$

although much fainter in colour, had absorbed 0·95 per cent. of Al_2O_3 and 0·11 per cent. of Fe_2O_3. The first glass was distinctly yellowish-green, whilst the latter was only tinged with bluish-yellow.

(3) From this it would appear that iron compounds in potash glasses do not colour the glass so highly as in soda glasses. This may mean that iron–potash–silicate is not coloured as deeply as iron–soda–silicate. It is impossible to formulate any definite statement as to the cause of this colour difference in the two types of glass, and further research is necessary on the matter.

(4) The fact that potash glasses are always more brilliant than soda glasses is a very striking one. There is no doubt upon the question when soda glasses are compared with corresponding potash glasses. The former always have a more muddy, more "dead" appearance. Lead glasses owe their brilliance, compared with lime glasses, to their higher refractive index. Refractive index alone does not explain the higher brilliancy of the potash–lime–silicate glasses compared with the soda series, as the latter have the higher refractive index. The explanation may be found in the fact that, first of all, soda glasses tend to weather the quicker, and so become dull more rapidly, and, secondly, the above-mentioned coloured silicates may help to "deaden" the appearance of the soda glasses. The fact that freshly broken soda glasses often appear indistinguishable from potash glasses lends weight to the first view. To test the second view, the two types of glass might be melted from pure materials in platinum vessels.

General Summary and Conclusions.

(1) Comparisons have been made of several properties of glass of the type $100SiO_2,yR_2O,xCaO$, where R_2O may be Na_2O, K_2O, or equimolecular Na_2O,K_2O mixtures, y varying between 20 and 40 molecules, and x between 5 and 40 molecules.

(2) In addition, the two molecular series $100SiO_2,20Na_2O,xCaO$ and $100SiO_2,13{\cdot}16K_2O,xCaO$ have been studied, the percentages of Na_2O in the first series being the same as the percentages of K_2O in the second.

(3) Further, a series of glasses has been investigated where the

Na_2O and K_2O are equivalent from the point of view of actual percentage weights. In this series, several sets of glasses were studied, each oxide being kept constant in turn and the other oxides varying.

(4) *Density.*—(*a*) From a molecular point of view, the glasses of the series $100SiO_2,40Na_2O,x CaO$ are all higher in density than the corresponding K_2O glasses.

(*b*) In the series $100SiO_2,20R_2O,x CaO$, the Na_2O glasses are higher in density than the K_2O glasses when x is greater than 7 molecules.

(*c*) The glasses of the $100SiO_2,20Na_2O,20K_2O,x CaO$ and

$$100SiO_2,10Na_2O,10K_2O,x CaO$$

series have densities intermediate between those of the corresponding Na_2O and K_2O series.

(*d*) From the viewpoint of equivalent percentage of Na_2O and K_2O by weight, the other oxide percentages being the same, the soda glass has the higher density.

(*e*) When the percentage of Na_2O in a glass is substituted by K_2O, the resultant glass has a density intermediate between the glasses containing Na_2O and K_2O alone.

(*f*) The following constants have been found to represent increase of density with variation of composition:—

$+1\%CaO-1\%Na_2O$ (silica constant) $=0{\cdot}0056$
$+1\%CaO-1\%K_2O$ (silica constant) $=0{\cdot}0077$

$+1\%CaO-1\%SiO_2$ (Na_2O constant) $=0{\cdot}0142$
$+1\%CaO-1\%SiO_2$ (K_2O constant) $=0{\cdot}0119$

$+1\%CaO-\frac{1}{2}\%SiO_2-\frac{1}{2}\%Na_2O$ $=0{\cdot}0094$
$+1\%CaO-\frac{1}{2}\%SiO_2-\frac{1}{2}\%K_2O$ $=0{\cdot}0093$

or the addition of 1 per cent. of CaO to a glass of the

$$aSiO_2,bR_2O,cCaO$$

type, where $a=60$ to 70 per cent., $b=10$ to 25 per cent., $c=5$ to 20 per cent., and $(a+b+c)=100$ per cent., results in a rise in density of 0·009, whether R_2O is represented by Na_2O or K_2O, when the consequent 1 per cent. fall is shared equally by the CaO and R_2O.

(5) *Refractive Index.*—(*a*) From the viewpoint of equal percentage proportion by weight, the soda-lime–silica glasses have a higher refractive index for the *D* line and a higher total dispersion than the corresponding potash–lime–silica glasses. Thus the substitution of the whole or part of the Na_2O in these glasses by K_2O, in equal amount by weight, will always result in a decrease in refractive index of the *D* line and in the total dispersion.

(*b*) The following constants have been found:—

	Increase in η_D.	Increase (in $F - C$).
+ 1% CaO − 1% Na_2O (silica constant)	0·00206	0·000018
+ 1% CaO − 1% K_2O (silica constant)	0·00208	0·000026
+ 1% CaO − 1% SiO_2 (Na_2O constant)	0·00294	0·000086
+ 1% CaO − 1% SiO_2 (K_2O constant)	0·00273	0·000096
+ 1% CaO − ½% SiO_2 − ½% Na_2O	0·00250	0·000052
+ 1% CaO − ½% SiO_2 − ½% K_2O	0·00240	0·000061

(6) In the alkali–lime–silica glasses, Na_2O is a better flux than K_2O when added in equivalent amount by weight.

(7) In two corresponding Na_2O and K_2O glasses, the one containing Na_2O has the *lower melting point*.

(8) *Devitrification* is more easily induced in Na_2O glasses than in K_2O glasses. In the case of glasses containing high CaO, increasing the silica content tends to prevent devitrification, whilst increasing the alkali helps it. Glasses which tend to deposit silica are improved by the addition of CaO. The addition of alkali may enhance the tendency to separation.

(9) The *Solubility* in water of glasses containing Na_2O is greater than the corresponding K_2O glasses where the K_2O is substituted in equivalent percentage by weight. Glasses containing equal weights of Na_2O and K_2O have a solubility below either the corresponding soda or potash glass.

(10) From the equivalent molecular viewpoint, Na_2O glasses are better than K_2O glasses for weathering. Viewed from the point of view of equivalent percentage weights, potash glasses are better than sodium.

(11) Taking the whole of the glasses and discussing them from the points of view (i) of general use, (ii) optical use, the following remarks are to be made:—

(*a*) No glass in the molecular series $100SiO_2,40R_2O,xCaO$ is of use either optically or otherwise, being debarred by tendency to devitrify or bad weathering properties.

(*b*) In the series $100SiO_2,20R_2O,xCaO$, the following glasses, and glasses in their near vicinity, could be made use of for general work:—

(i) $100SiO_2,20Na_2O,20CaO$.
(ii) $100SiO_2,20K_2O,20CaO$.
(iii) $100SiO_2,10Na_2O,10K_2O,20CaO$.

All the rest of the glasses would fail, owing either to devitrification tendencies or to bad weathering properties.

It should be noted that each glass can be expressed by the simple molecular formula $5SiO_2,1R_2O,1CaO$. For many years, attempts have been made to find a formula which shall represent the best glass and serve as a basis for melting schemes. The formula which has received the most approbation has been $6SiO_2,R_2'O,R''O$, where $R_2'O$ represents any of the alkali oxides and $R''O$ any of the oxides of Ca, Ba, Pb, Zn, or mixtures of these oxides. In the opinion of the author, this formula, known as the Benrath formula, is not so suitable for the best lime–alkali–silicate glass as the formula above, worked out in the present series of papers. In the first place, the glasses $6SiO_2,R_2O,CaO$ would be somewhat difficult to melt, and although slightly superior in durability to the $5SiO_2,R_2O,CaO$ glasses, would exhibit distinct tendencies to devitrification, particularly the $6SiO_2,Na_2O,CaO$ glass, especially under the rigorous conditions of cooling demanded in optical glass.

The percentage compositions of the three glasses above, expressed in round numbers, would be:—

(1) SiO_2 72, Na_2O 15, CaO 13,
(2) SiO_2 67, K_2O 21, CaO 12,
(3) SiO_2 70, Na_2O 7, K_2O 10, CaO 13,

and batches for each would be:—

(1) $SiO_2=720$, $Na_2CO_3=256$, $CaCO_3=232$ parts by weight
(2) $SiO_2=670$, $K_2CO_3=308$, $CaCO_3=214$,, ,,
(3) $SiO_2=700$, $K_2CO_3=147$, $Na_2CO_3=120$, $CaCO_3=232$ parts by weight,

the Na_2CO_3 and K_2CO_3 being taken as pure and dry.

Narrowing the issue, and regarding the use of these three glasses in optical work, they could all be employed if the refractive indices they give were required, but they would not be of first-class durability. Classifying them according to the scheme previously worked out, the Na_2O glass and the Na_2O,K_2O glass would probably be placed in Class III and the K_2O glass in Class IV.

(*c*) Turning now to the glasses worked out according to their equivalent weight percentages, the following would be best for general use from the point of view of durability and non-devitrification:—

(1) $70SiO_2,15Na_2O,15CaO$.
(2) $70SiO_2,7{\cdot}5Na_2O,7{\cdot}5K_2O,15CaO$.
(3) $70SiO_2,15K_2O,15CaO$.
(4) $70SiO_2,20CaO,5Na_2O,5K_2O$.
(5) $70SiO_2,20CaO,10K_2O$.
(6) $65SiO_2,20CaO,15K_2O$.
(7) $65SiO_2,15CaO,20K_2O$.
(8) $60SiO_2,20CaO,20K_2O$.

It will be seen that only one of these glasses is purely a Na_2O glass, that being the one in the vicinity of the molecular

$$5SiO_2,Na_2O,CaO$$

type. All the remaining glasses are more difficult to melt than this Na_2O glass, and of the above glasses, Nos. 4 and 5 would probably require temperatures above the usual glass works practice.

From an optical point of view, all the above glasses could be used, Nos. 4 and 5 being in Class I, Nos. 2, 3, and 7 in Class II, No. 8 in Class III, and No. 6 in Class IV.

(*d*) It is of interest to compare the durability with the order of melting of glasses given in the last column of Table XII on p. 92. It will be seen that the more difficult a glass is to melt, the better it will be from a durability point of view and the less soluble in water.

The author desires to thank the Directors of Messrs. Wood Bros., Ltd., Barnsley, and of the Derby Crown Glass Co., Ltd., for permission to publish the foregoing research. In particular, he would like to record his thanks to Mr. W. F. J. Wood, C.B.E., B.Sc., F.I.C., for the kindly interest he has taken in the work throughout, for his friendly criticism, and never-failing encouragement.

It is with feelings of gratefulness, too, that the author would also acknowledge the help, encouragement, and advice he has received from his colleagues, both at Derby and Barnsley.

THE RESEARCH DEPARTMENT,
WOOD BROS. GLASS CO., Ltd.
BARNSLEY.

THE RESEARCH DEPARTMENT,
DERBY CROWN GLASS CO., Ltd.
DERBY.

VI.—*A Suggested Improvement in the Manufacture of Glasshouse Pots.*

BY LIEUT.-COL. C. W. THOMAS.

(*Read at the Stourbridge Meeting, January* 21*st*, 1920.)

THE object aimed at in the author's device is to enable the interior surface of the pot to be worked upon when in a hard and toughened condition. It is known that the life of the pot is improved if this can be done, and it is the ordinary practice on the Continent with pots which are made in moulds to beat the inside surface after it has become hard with a beater in order to produce a dense and tough skin.

In the case of covered pots, it is impossible to do this, because the required condition of hardness and toughness is not reached until some time after the crown has been put on.

It has previously been suggested to make a covered pot in two halves, the lower part being approximately an ordinary open pot, and the crown being made separately and placed in position afterwards. The chief objection to this is that anything in the nature of an open joint between the two parts of the pot would permit of the ingress of dust or furnace gases. To obviate this, it is proposed to fit a jointing cushion of asbestos rope between the two portions, each of which is suitably grooved to hold the packing in position.

From the result of a similar adaptation of an asbestos cushion for other work, it is found that it makes a thoroughly effective gas-tight and dust-tight joint, and it can be applied either loose or, if desirable, can be cemented into the groove with a suitable fixative.

The particular pot shown in Figs. 1, 2, and 3 has been made in a solid mould with a core, the clay being wrought into a suitable condition and rammed into a dense body with a wooden rammer during the process of manufacture. This results, as will be seen, in a much stronger and denser body than the ordinary hand-built pot, and the process has the additional advantage that any desired proportion of grog can be made use of without the usual disastrous results on the pot-maker's hands.

The pot was made partly as an experiment to test the soundness of the author's views on the method of manufacture, and he would be glad to receive any criticisms which may be offered.

It should be added that the arrangement shown is not patented, and that it is put forward as a suggested improvement in pot making which is quite open to the trade as a whole.

Messrs. E. J. and J. Pearson, Ltd.
Stourbridge.

Discussion.

Mr. J. S. Williams-Thomas said the chief point he doubted was that, unless the loose top fitted well, the furnace flames would come through and injure the metal and the article which was being made. A further doubt was whether the expansion of the top and bottom would be equal when heated in the furnace. The

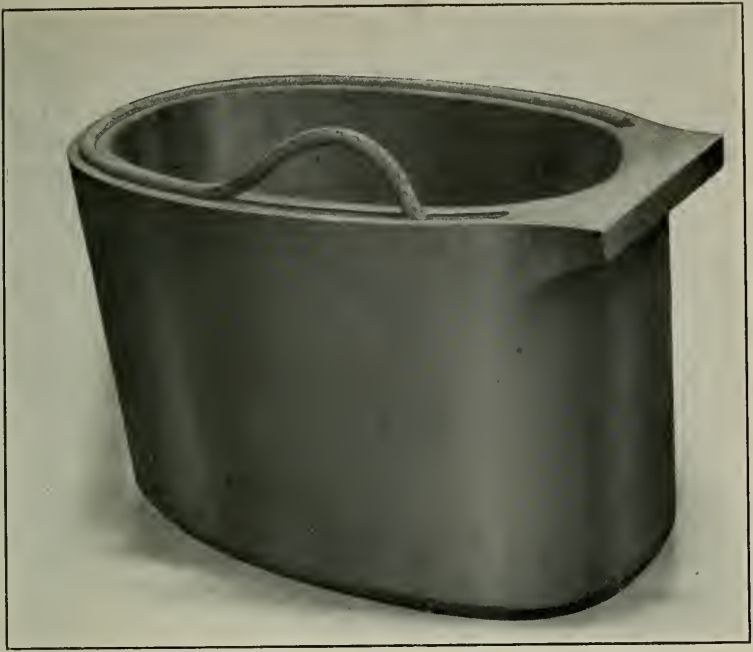

Fig. 1.

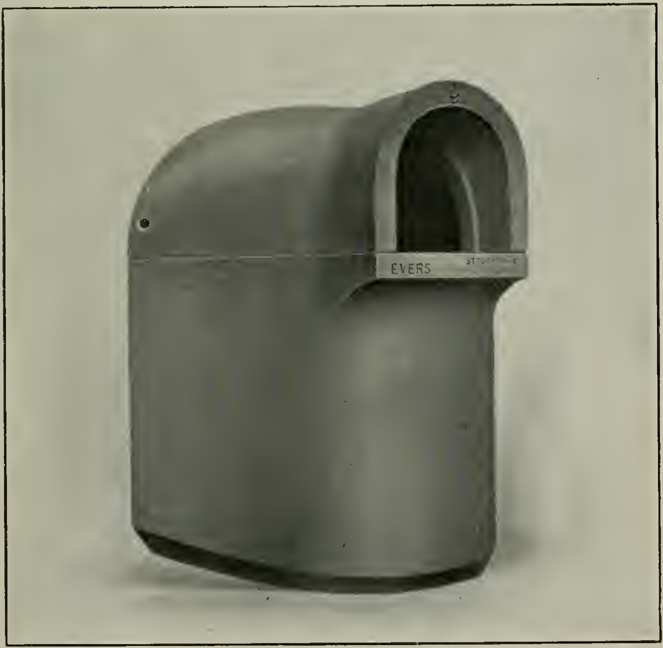

Fig. 2.

[*To face Trans*, *p.* 108.

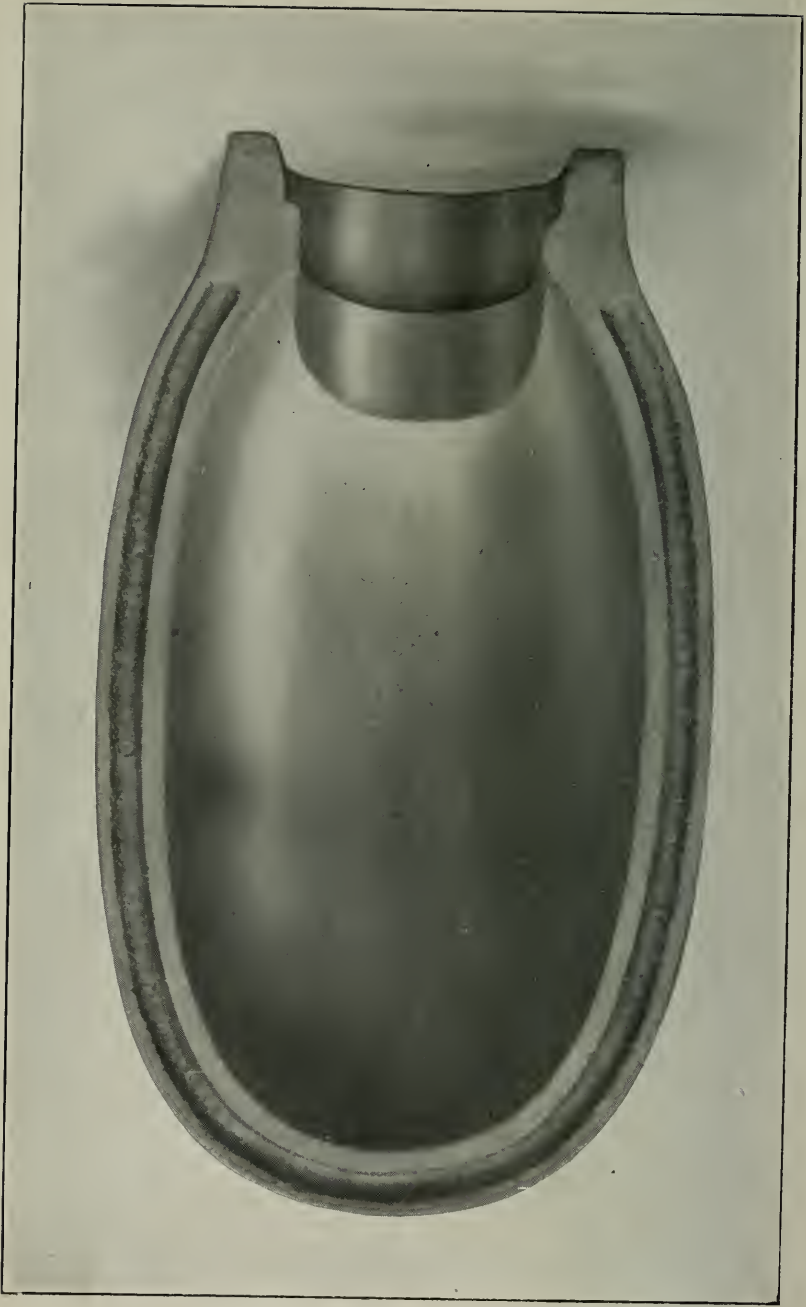

FIG. 3.

pot would be very useful if expansion and contraction were equal throughout. This could only be ascertained by trial.

Mr. R. H. H. Wood asked whether it was proposed to get both parts of the pot in the oven at the same time.

Dr. M. W. Travers thought the pot should have a trial. There was the chance, however, that glass might ooze through the joint. The asbestos ring would dissolve out after being in a hot furnace for a week or two, and a number of small holes would appear round the asbestos. There was also the likelihood of trouble arising owing to air being drawn in.

Mr. J. Northwood thought that sincere thanks were due to Col. Thomas for introducing a new method for making English pots. He referred particularly to the latter part of the paper, describing how the clay was rammed up in the walls. When in Germany a few years ago he had had an opportunity of learning that the mode of procedure there was very different from that used in this country. The foreign method seemed to him to be the better, the clay being beaten up from the bottom. He was glad to see, however, that steps were being taken to make a pot which was denser and more stable. His criticism of the pot exhibited to the meeting was that the asbestos ring would not stand the heat of the furnace, and would perish. He also thought that the back end of the top part would contract more than the front. A cavity would be formed, and the utility of the pot destroyed. He would like to see the pot tried, however.

Mr. J. Gardiner referred to hammering out water from the clay. He thought the water should be coaxed out.

Mr. Norman S. Bache was of the opinion that the process suggested would enable pots to be turned out quicker than hitherto. This fact alone would entitle it to serious consideration. Unhappily, they had recently lost by death several very good pot-makers. Only by some speeding-up process could manufacturers be given what they wanted when they wanted it. Already the shortage of glass pots throughout the country was becoming critical.

Mr. S. N. Jenkinson said that Col. Thomas had set out with the idea of getting a denser body and quicker drying, and the only way he was able to do this was by making the pot in two parts. He suggested that a thoroughly effective pot would never be realised until the British fireclay manufacturer adopted the system of making up mixtures of clays drawn from different districts instead of confining himself to a particular seam of clay which he himself owned. If Col. Thomas and other manufacturers in that district would act upon those lines, he was convinced they would soon see progress. At present it was doubtful whether any firm contained in its clay seams all the materials necessary for the best pots. In Germany clays were brought in and mixed as taught by research work and experience. This practice has certainly justified itself. The Society owed Col. Thomas a vote of thanks for doing what he had done. Glass manufacturers wanted the clay trade to assist them.

Col. C. W. Thomas, replying, said he was not prepared to back his opinion as to the length of the life of asbestos; all he knew was that in a similar sort of position, where the temperature was nearly as high, it had lasted for a period of seven years. If it would last, or if any other material could be found, they need have no fear whatever as to the passage of flame, gases or dust, or similar material through the joint. This statement was based on the effect he had observed with asbestos rope under other conditions of work. If they had a suitable joint, asbestos or otherwise, properly fitted in the groove, any relative movement between the top and bottom would not be so great as to produce any instability at the top, and it would not be beyond the elastic limits of the packing piece in between. He had seen the manufacture of pots on the Continent, and had also seen cast pots. The future of these was, he thought, a little uncertain at present. Whether the process before them could be improved sufficiently to make it of practical use he did not at present know, but he hoped to be able to tell them more about it on some future occasion. As to the buying of clays, he quite agreed with their President. Only in comparatively late years now had it been possible to obtain for glass manufacturers anything like adequate information as to the behaviour of the pots, the conditions under which they had to work, and what the effect of their life in the furnace had been on the clay. This, largely owing to the activities of this Society, was likely to become a thing of the past, and they might look forward in the future to being able, not only to obtain more definite and accurate information, but they ought before very long to be in a position to send a sample of clay or a mixture of clays to some responsible and competent person, who could tell them what were their probable advantages and their possible disadvantages for any given purpose. Hitherto, both those who used glasshouse pots and those who made them had been working more or less in the dark. He was only too glad to think that the handicaps under which they had suffered were in a fair way to be removed. It would make it much pleasanter, and was going to make it very much better, for the glass industry. Research work, to his mind, was the whole essence of the matter. From his experience as a manufacturer, he was convinced that the more interested they could get their staffs and workpeople in research and in the application of scientific methods and scientific knowledge to their everyday processes, however simple these might be, so much the better it would be for the industry as a whole, and, in this case, the glass industry in particular.

VII.—*The Optical Properties of some Lime-Soda Glasses.*

By J. R. Clarke, M.Sc., and W. E. S. Turner, D.Sc.

The measurements recorded in this paper refer to the series of lime-soda glasses, the composition and various properties of which have already been described in previous papers.[*] It is not imagined that the series of glasses investigated, namely, those of the trisilicate type between $6SiO_2,2Na_2O$ and $6SiO_2,Na_2O,CaO$, is sufficiently wide to satisfy the designer of optical instruments, but the results at least serve to demonstrate the influence of lime, relative to soda, on some of the fundamental optical constants.

Despite the mass of data published by the Jena school of workers, the relation of such a property as the refractive index to the chemical composition was by no means clearly defined. The complex compositions of the optical glasses used, such as those published in Hovestadt's "Jena Glass," preclude any but the most general conclusions to be drawn. So far as we are aware, the first investigation which attempted to establish definite relationships between refractive index or specific refraction and composition was that of Larsen,[†] who showed that, in the case of lime-magnesia silicate glasses, and of glasses consisting of the mixed felspars *albite* and *anorthite*, the relation between refractive index and composition, as also between specific refraction and composition, was practically a straight line, or, in other words, was nearly additive.

Two subsequent papers by Tillotson[‡] led to very similar conclusions. These papers concerned, the one a series of lime-soda glasses, and the other, glasses of the Na_2O,CaO,SiO_2, the Na_2O,BaO,SiO_2, and the *albite-anorthite* series. The latter paper embodied the results of a study of the refractive index as a means of determining the presence and nature of compounds in glasses.

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[*] This Journal, Trans., 1919, **3**, 223, 228, 238, and 260.

[†] Larsen, *Amer. J. Sci.*, 1909, **28**, 263.

[‡] *J. Ind. Eng. Chem.*, 1912, **4**, 446. *J. Amer. Cer. Soc.*, 1918, **1**, 76.

In both papers, further evidence was brought forward that both refractive index and specific refraction were additive functions, or nearly so, of the compositions.

In Larsen's investigations, indices of refraction were measured for lithium, sodium, and thallium light; in Tillotson's, white light only. For the purpose of the optical instrument-maker, the standard sources of light are those of the *C*, *F*, and *G′* lines, and the sodium *D* line, and measurements of the refractive indices for these lines have been made by us. In addition, for the sake of general information, measurements have been made of the position of the ultra-violet absorption band.

For the purposes of the tests, the glasses were prepared from annealed slabs, which were cut and then optically polished with plane parallel faces. The measurements of refractive index were made by means of the Pulfrich refractometer, repeated tests with different specimens of the glasses giving results agreeing to a unit in the fourth place of decimals. Owing to the faintness of the *G′* line, however, the values of refractive index, μ_G, cannot be regarded with such certainty. The absorption tests were carried out with a Hilger quartz spectrograph, using an iron arc as source of light, the plates being over-exposed in order to get a definite limit of transmission. It was found that the wave-length transmitted decreased with time to a true minimum, and this was the wave-length measured. With the iron arc, the position of the absorption band could accurately be determined. The plates were sensitive to light up to a wave-length of 7000 Å.U., but in no case was absorption shown in this region.

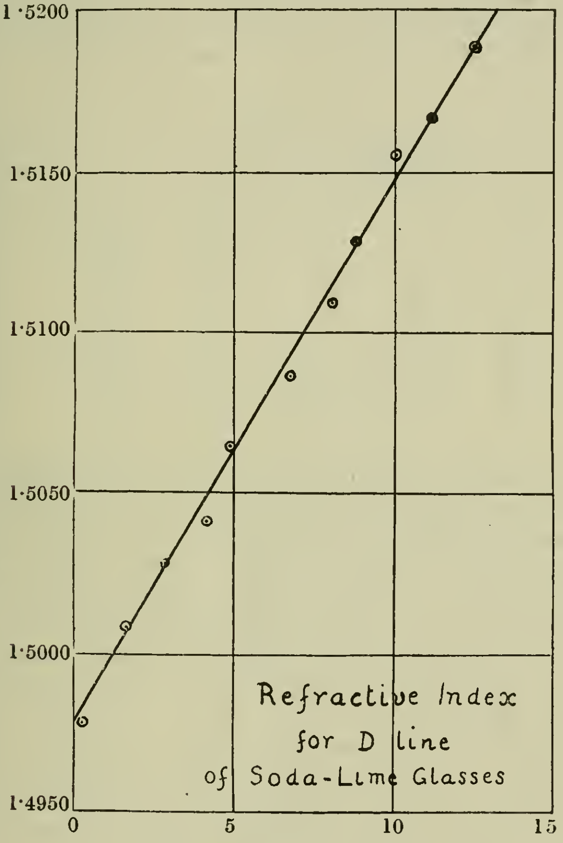
Table I contains the results of the measurements of refractive index, μ_C, μ_D, μ_F, and μ_G, that is, for the lines *C*, *D*, *F*, and *G′*, as well as the density, *D*, for comparison. The composition of the glasses have been set out in a previous paper, but it may be stated that glass No. 1 is $Na_2O,3SiO_2$, and that in each succeeding glass 0·1Na_2O is replaced by approximately 0·1CaO until the composition of No. 11 is $Na_2O,CaO,6SiO_2$.

TABLE I.

Glass No.	μ_C.	μ_D.	μ_F.	$\mu_{G'}$.	Density.
1	1·4949	1·4977	1·5066	1·5120	2·4353
2	1·4982	1·5007	1·5068	1·5123	2·4384
3	1·4996	1·5027	1·5083	1·5147	2·4416
4	1·5016	1·5041	1·5102	1·5167	2·4462
5	1·5038	1·5063	1·5124	1·5178	2·4507
6	1·5060	1·5085	1·5146	1·5189	2·4602
7	1·5084	1·5108	1·5171	1·5217	2·4650
8	1·5101	1·5127	1·5188	1·5241	2·4682
9	1·5128	1·5154	1·5215	1·5267	2·4757
10	1·5142	1·5168	1·5229	1·5289	2·4840
11	1·5164	1·5188	1·5250	1·5317	2·4904

Two conclusions are at once apparent from these results, namely, that the replacement of the soda molecularly by lime results in a steady increase in the refractive index for all lines of light used, and, secondly, that the refractive index increases more or less as the density increases.*

The accompanying figure indicates that in the trisilicate series of lime-soda glasses, the relationship between composition and refractive index may be assumed, without serious error, to be linear. It must be remembered that the analytical composition is plotted against the refractive index, and possible error in analysis of 0·1 to 0·2 per cent. in the CaO content will shift the points distinctly from the straight line. From the curve, it is clear that in the trisilicate



Molecules per cent. of CaO.

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* Compare Larsen and Tillotson, *loc. cit.*

glasses each substitution of 0·1 molecule of Na_2O by 0·1 molecule of CaO results in an increase of refractive index for the D line of approximately 0·0020. Attention may be directed to the fact that less accurate results for the refractive indices are probably obtained with glass No. 1, $Na_2O,3SiO_2$, since this is very susceptible to the action of atmospheric moisture.

Table II contains the values of (1) the total dispersion $F-C$, the partial dispersions $D-C$, $F-D$, and $G'-F$; (2) the value of ν; (3) the position of the ultra-violet absorption band.

Table II.

	Dispersion × 10^4.					Limit of transmission in A.U.
Glass No.	$F-C$.	$D-C$.	$F-D$.	$G'-F$.	ν.	
1	117	28	89	54	42·6	2954
2	86	25	61	55	58·6	2825
3	87	31	56	64	58·6	2912
4	86	25	61	65	58·7	2844
5	86	25	61	54	58·6	3019
6	86	25	61	43	58·9	2912
7	87	24	63	46	58·8	2967
8	87	26	61	53	58·9	2948
9	87	26	61	52	59·0	2924
10	87	26	61	60	59·5	2969
11	86	24	62	67	59·7	3019

It will be seen that, except for glass No. 1, the dispersions and values of ν are practically constant throughout the series of soda-lime trisilicate glasses. It is possible that a distinct change in optical properties is brought about by the first introduction of lime into the series of glasses, but the hygroscopic character of glass No. 1 may, on the other hand, account in part for the low number for this glass. The greater variations in the values $G'-F$ may certainly be assigned to the difficulty of obtaining readings for the G' line.

In regard to the position of the ultra-violet light absorption band, it should be mentioned that all the glasses were slightly coloured, Nos. 1 and 9 being yellowish- and the remainder greenish-blue; No. 6 contained more iron and alumina than any other of the glasses. On the whole, it might be said that the limit of transmission remains fairly constant throughout the series.

Summary and Conclusions.

(1) The refractive indices and dispersions for the C, D, F, and G' lines, the value of ν, and the limit of transmission of ultra-violet light, have been determined for the series of glasses $2Na_2O,6SiO_2$–$Na_2O,CaO,6SiO_2$.

(2) The refractive index for the *D* line is practically an additive property of the composition.

(3) The refractive indices undergo regular increases as replacement of Na_2O takes place by CaO. For the *D* line, replacement of each 0·1 molecule of Na_2O by 0·1 molecule of CaO increases the refractive index, on the average, by 0·0020.

(4) The total and partial dispersions and values of ν are practically constant throughout the series of glasses examined. The dispersion is greatest between the *D* and *F* lines and least between the *C* and *D*.

(5) The position of the ultra-violet absorption band has been determined. It remains fairly constant at about 2950 Å.U., the glasses being very transparent to ultra-violet light.

THE DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

VIII.—*The Thermal Expansion of Magnesia-containing Glasses.*

By S. ENGLISH, M.Sc., and W. E. S. TURNER, D.Sc.

THE question of the thermal expansibility of magnesia-containing glasses is a matter of considerable interest and importance. It is commonly supposed that magnesia exerts a supremely beneficial effect on glass by reducing its coefficient of expansion, and for this reason, mainly, has been added to glasses, for chemical, illuminating, and heat-resisting purposes. The chief ground for this belief undoubtedly lies in the results of Schott, who calculated * the factors representing the contribution which each oxide made to the expansion of a glass. Whereas the factor for the increase of the cubical coefficient of expansion due to the addition of each 1 per cent. of silica was $0{\cdot}8 \times 10^{-7}$, that for boric oxide and for magnesia were both only $0{\cdot}1 \times 10^{-7}$, a result which, if correct, would make magnesia of very great value as a glass constituent. A glass composed of silica, boric oxide, and magnesia would thus possess an exceedingly small thermal expansion.

If the effect of magnesia is really as reputed, there is undoubtedly a difference between the behaviour of magnesia in the glass and magnesia in a magnesia brick. From the measurements of Hodsman and Cobb,† the mean coefficient of expansion of a magnesia brick previously fired at cone 9 is, between 15° and 1000°, 1274×10^{-8}, whereas, if the magnesia had the same expansion in the bulk form as it is reputed to have in glass, the coefficient (linear) should be 33×10^{-8} only. There is thus a great divergence.

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* *Ann. Physik.*, 1894, **51**, 735.

† This JOURNAL, *Trans.*, 1919, **3**, 201.

To imagine that magnesia in a brick and magnesia in glass, combined as it is undoubtedly to form magnesium silicate, should show resemblances in properties involves a big assumption, although one has to bear in mind that some of the properties of glasses can be connected in an additive manner with the properties of the constituent oxides. We refer again later in this paper to the same subject. It may be that electrically shrunk magnesia, or fused magnesia, would exhibit a very low rate of expansion. Undoubtedly it undergoes great change of properties on fusion; for example, the density rises very considerably, and it is more than likely that the thermal expansion diminishes.

The whole subject is therefore of very considerable interest, and because of it, and in pursuance of our attempts systematically to work out the properties of glasses of different composition, we have determined the coefficients of expansion of the trisilicate series of magnesia glasses previously described.*

The method employed was the dilatometric one referred to when investigating the lime glasses,† the range of temperature being approximately 25° to 90°. The glass dilatometers were all annealed before being used for experiment. The results are contained in Table I, where, for the sake of avoiding cross references, the compositions of the glasses are repeated.

TABLE I.

Glass No.	Percentage composition.				Temp. range.	Mean linear coeff. of expn. $\times 10^8$.
	SiO_2.	MgO.	Na_2O.	CaO,Fe_2O_3 and Al_2O_3.		
1	—	—	—	—	25·2—90·0°	1138
24	74·07	1·10	24·23	0·37	25·8—90·6	1111
25	74·35	1·85	23·46	0·75	24·0—89·8	1064
26	75·00	2·49	22·12	0·26	24·0—89·1	1005
27	75·16	3·47	20·69	0·46	25·0—89·8	947
28	75·19	4·20	19·83	0·52	25·0—90·5	895
329	76·30	5·09	18·26	0·74	24·5—90·6	841
330	77·09	6·10	16·05	0·68	25·0—90·0	784
331	76·68	6·87	15·77	0·93	25·0—90·0	754
332	76·86	7·46	14·55	0·93	25·0—90·0	710
389	77·77	8·45	13·40	0·56	25·0—90·0	645
390	78·28	9·30	11·76	0·91	25·0—90·0	594

There is evidently a great reduction in the thermal expansion as magnesia replaces soda, and at least the last two members of the series may claim to be heat-resisting glasses and might be useful commercially were it not for their difficult working properties.

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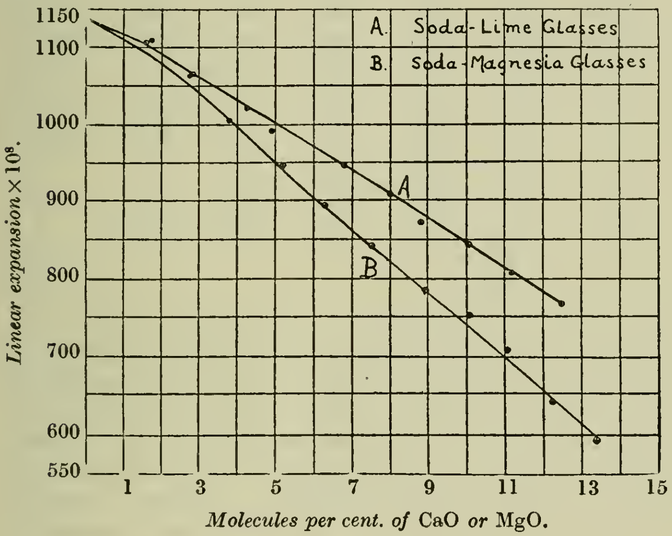
* This JOURNAL, Trans., 1919, **3**, 275, 278.

† *Ibid.*, 1919, **3**, 238.

In the accompanying figure the above results are set out graphically together with those of the lime–soda glasses previously investigated. For the purpose of comparison, the compositions employed are the molecular percentages of lime or magnesia, as the case may be.

Save for the initial inflection, the graph of the magnesia results is a straight line, affording a further example of the fact that the coefficient of expansion is an additive property of the composition. The slope of the magnesia curve as compared with that for lime indicates that magnesia has a very considerable advantage over lime in diminishing the coefficient of expansion. In the early glasses of the two series this advantage of the magnesia glasses does not appear, and the two curves are nearly coincident. It must be noted, however, that it is certainly not easy to determine the coefficient of expansion with an error less than 1·0 per cent.



The slope, however, does not suggest that there is such an extraordinary difference between the effect of magnesia and lime as the difference between Schott's factors for these two oxides implies, and we resolved to test the results both by calculating the coefficients of expansion of the glasses by Schott's system and by independent evaluation of our own.

So far as can be ascertained, Schott's factors were deduced empirically from observed expansions of glasses in which, in the case of magnesia, very small percentages only were present, rendering deduction therefore uncertain. We prefer to adopt some basis for calculations other than empirical, and as a first assumption we shall consider that the oxides in the fused amorphous condition take with them into the glass their own thermal expansions. In the case of the specific heat, there is some warrant for such an assumption, but so far as we are aware, no direct evidence of similar character in regard to the coefficient of expansion exists. Such evidence being wanting for the present, the assumption may be judged by the value of the results.

As a starting point, we have assumed the coefficient of linear expansion of fused silica to be the same as that of SiO_2 in combination in glass, namely, 5×10^{-7}. With this as starting point, it is possible to determine a value for Na_2O in glass No. 1, namely, $Na_2O,3SiO_2$. Then, in turn, values for CaO or MgO may be determined. Thus, for glass No. 1, if x is the amount by which the coefficient of linear expansion is increased for each 1 per cent. increase of Na_2O, we have the following equation:

$$73{\cdot}97 \times 5 \times 10^{-7} + 25{\cdot}37 \times x \times 10^{-7} = 100 \times 113{\cdot}8 \times 10^{-7}.$$

For magnesia in glass No. 7 we have, if y is the required expansion factor for MgO:

$$74{\cdot}05 \times 5 \times 10^{-7} + 7{\cdot}56 \times y \times 10^{-7} + 17{\cdot}3 \times 434 = 91{\cdot}1 \times 10^{-7}.$$

Proceeding in this way, it is possible to build up a table of factors on a rational plan, the values of x and y being determined by the mean for the whole series. As a matter of fact, the factors we have employed are not the precise mean of those derived from the whole series of glasses, but we have attempted to make allowance for divergences due to the amount of impurity in the glass. The new factors arrived at are quoted in Table II, side by side with Schott's values. The latter are for cubical expansion, and since our own are deduced for linear expansion, they must, for comparison, be multiplied by 3.

TABLE II.

Oxide.	Schott's factors.	English and Turner.
SiO_2	0·8	0·05 × 3
Na_2O	10·0	4·32 × 3
CaO	5·0	1·63 × 3
MgO	0·1	0·45 × 3

It will be seen that whereas we agree closely with Schott in regard to the figure for CaO whilst the number for Na_2O is of the same order, there is a marked difference for SiO_2 and a still greater divergence for MgO. Thus, MgO does not possess the exceptional virtue which Schott claimed. In order to illustrate the value of the factors, we have calculated the coefficients of linear expansion (1) by Schott's factors, (2) by our own, and set them side by side with the observed values in table III.

TABLE III.

	Lime glasses. Linear expansion × 10^8.				Magnesia glasses. Linear expansion × 10^8.		
Glass No.	Calc. by Schott.	Obsd.	Calc. (2)	Glass No.	Calc. by Schott.	Obsd.	Calc. (2)
1	1053	1138	1133	1	—	1138	—
2	1036	1106	1109	24	1011	1111	1088
3	1013	1065	1072	25	993	1164	1060
4	993	1021	1039	26	942	1005	1005
5	981	988	992	27	899	947	954
6	958	947	966	28	871	895	913
7	916	911	907	329	826	841	849
8	886	870	873	330	754	784	758
9	862	844	835	331	748	754	750
10	850	810	812	332	708	710	700
11	822	769	770	389	666	645	656
16	923	881	868	390	619	594	589
17	789	801	802				

In the case of both the lime and the magnesia glasses, the values calculated by Schott's factors start 8 to 10 per cent. below the observed results, but ultimately exceed them. By the use of our own factors, very much closer agreement is obtained. It may be remarked that a comparatively small error in the analysis of the glass for alkali (soda) will have a very considerable effect on the calculated coefficient of expansion. Bearing this in mind, the agreement is good.

The test of the new factors obviously depends on their applicability to glasses of diverse composition.

Unfortunately, we have no data available on the expansion of commercial magnesia-containing glasses containing only silica, soda, lime, and magnesia, so that a test is not yet possible. In the case of lime glasses, Schott's glass No. 59 has the percentage composition SiO_2, 73·2; As_2O_5, 0·3; Na_2O, 18·5; CaO, 8·0; and a linear expansion of 966×10^{-8}. Calculation by our factors, neglecting the very small amount of As_2O_5, gives the value 966×10^{-8} also, Schott's calculated value being 946×10^{-8}.

We hope to be able to deal more fully with the subject at a later date, and to be able to examine glasses melted in a non-corrodable container from pure materials so as to be able to avoid the uncertain effect of small quantities of impurities.

Summary and Conclusions.

1. The thermal expansions of a series of soda magnesia glasses have been determined for the temperature range 25—90°.
2. The coefficients of expansion are found to be an additive property of the composition.
3. Replacement of soda by magnesia in a glass causes rapid diminution in the thermal expansion.
4. Magnesia is much more effective than lime in reducing thermal expansion of glass, but is not nearly so abnormal in this respect as Schott stated.
5. New factors for soda–lime and soda–magnesia glass constituents have been deduced, leading to closer agreement between observed and calculated expansions than can be obtained by Schott's factors.

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IX.—*The Comparative Effects of Soda and Potash in Lead Glass for Table Ware.*

By F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

(*Read at the Stourbridge Meeting, January 21st,* 1920.)

The scarcity and consequent high price of potash in this country during the war led to a very great reduction in its use, and to the substitution of soda in its stead. We have from time to time been consulted in regard to troubles experienced as the result of this substitution. Some of them were due to replacement of potash by soda weight for weight instead of in molecular proportion, but others have been due to specific differences in the effect of soda and potash. It seemed both of interest and importance to carry out some tests on glasses in commercial use in order definitely to ascertain in what way soda and potash-lead glasses differed in durability, in particular, but also in melting and working properties.

The Glasses Examined.

The glasses examined may be divided into three sets of three In the first, an actual commercial glass containing soda has been compared with two others in which the whole of the soda, other than that present as borax, was substituted molecularly by potash, and, in the third, soda and potash were present in equimolecular proportions.*

The second set was based on what may be regarded as the standard British crystal glass, the batch having previously been used in investigations carried out in this department.† Here, again, the standard batch was varied so that in the one case the potash was wholly replaced by soda, and in the other by one-half the equivalent of soda, this last glass thus containing equimolecular proportions of soda and potash.

During the course of the experiments we found that glasses of the first series yielded some rather remarkable results, which were considered likely to be due to the influence of the boric oxide present. Hence, a third set of glasses was prepared resembling the second, but with the addition of borax in the same proportion, per unit weight of sand, as in the first series.

The actual batch compositions were as follows:—

Series I.

	1.	2.	3.
Sand	504	504	504
Red lead	224	224	224
Borax	10	10	10
Soda-ash (95 per cent.)	144	72	—
Sodium nitrate	42	21	—
Potash	—	94	188
Potassium nitrate	—	25	50

	Series II.			*Series III.*		
	A.	*B.*	*C.*	*D.*	*E.*	*F.*
Sand	500	500	500	500	500	500
Red lead	330	330	330	330	330	330
Soda-ash	134	66	—	134	67	—
Sodium nitrate	21	10	—	20	10	—
Potash	—	83	165	—	83	165
Potassium nitrate	—	13	25	—	12·5	25
Borax	—	—	—	10	10	10

All the meltings of the first two series were made in small crucibles, each with a capacity for about 400 grams, or a little less than a pound, of glass, and in order that the temperature conditions might be maintained as uniform as possible, three pots were fired in the same gas furnace. The batch was added in two separate portions, the second twenty minutes after the first, at definite temperatures, namely, 1300°, 1350°, or 1400°, the melting carried out at 1400°, and the fining from 1400° down to 1250°. Fining occurred readily if the melting was carried out at 1400°, but was much more difficult if the melting temperature was 1300°. The operation of fining was best accomplished by running at 1400° for one and a half hours after the glass was batch-free, and then cooling off for an hour at 1300—1250°. The total time for the melting operation was about 3½ hours. From the melts thus made discs of glass were poured.

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* That is, 138 parts by weight of potash substituted 106 parts by weight of soda, and 101 parts of potassium nitrate substituted 85 parts of sodium nitrate.

† "The Effect of Small Quantities of Chlorides and Sulphates in Causing Opalescence in Glass," J. D. Cauwood and W. E. S. Turner, this JOURNAL, Trans., 1917, 1, 87.

The third series of meltings was carried out in pots of 28 lb. capacity running at a temperature of 1400°, the glass being worked at 1300° to 1325°.

The glasses made as described above have not been subjected to complete analysis, but as many as four different meltings of some of them have been made, and independent tests carried out on them with excellent agreement in the results.

Effect of Soda and Potash on Melting and Working.

Comparing the different series of glasses, those of Series I. were more fluid than those of Series II., whilst Series III. did not show any marked difference from Series II., despite the addition of a little borax. The difference of scale of melting, however, makes precise comparison impossible of Series II and III.

In regard to the effect of composition, the soda glasses undoubtedly melted more easily than either of the others, the wholly potash glass being the most difficult to melt. Not only were they most readily melted, but the soda glasses were most fluid and the potash most viscous. Although the mixed soda-potash glasses, in respect of fluidity and ease of melting, are intermediate between the soda and potash glasses, they appeared to become fine more readily than either.

The colour of the glasses was also of interest. The small pots used had a thin inner coating of China clay, but usually this was eaten through and attack on the main body of the pot occurred. In all cases it was found that the purely soda glasses were green in colour, the purely potash glasses colourless, whilst the mixed soda-potash had only a slight green tint, and more closely resembled the potash glasses than the soda. If colour is a true indication of the test of corrosion, then the obvious conclusion would be that the soda glasses cause most and the potash glasses least attack. It is probable, however, that the colour is not entirely connected with the extent of corrosion.

Tests on Durability.

In order to determine the durability of the glasses and the relative value of soda and potash in this respect, tests were carried out of the effect of water and of hydrochloric acid. A test with alkali was not included, as contact with such a medium is much less likely than with the others.

The water tests were carried out in the autoclave, the effect both of water and of steam being determined at temperatures 120° and 140°. The discs of the glass for the water test were immersed in water in a platinum basin and covered with platinum foil, whilst for the steam test the disc was supported by platinum wire points. The time required to reach 120° was fifty to fifty-five minutes, and to return to atmospheric pressure again, sixty to sixty-five minutes. The temperature was maintained at 120° for three hours. The time needed to reach 140° was eighty to ninety minutes, and to cool off about eighty to eighty-five minutes, three hours being the period of heating at 140°.

After the operation, the losses in weight were determined and calculated in terms of milligrams per 100 sq. cm.

For the hydrochloric acid test, the discs were boiled in acid of 20·24 per cent. strength for three hours, and the losses in weight calculated in a similar manner.

The results are collected in the following table:—

Losses sustained (mg. per 100 sq. cm.).

	Glass No.	Water.		Steam.		Hydrochloric acid.
		120°	140°	120°	140°	
I	1.........	2·7	3·7	3·4	6·5	1·07
	2.........	0·24	0·5	0·98	1·2	0·72
	3.........	3·0	4·0	5·0	7·6	2·4
II	*A*	3·2	6·6	2·0	3·1	0·7
	B	2·2	5·4	1·2	2·9	1·6
	C	4·4	11·4	2·4	3·7	0·97
III	*D*	1·8	5·8	1·1	2·2	0·6
	E	1·6	4·5	0·9	1·7	0·4
	F	2·1	8·4	1·3	2·3	0·7

Treatment with water or steam at 120° produced no visible effects on glasses 1, 2, 3, *B*, *D*, *E*, and *F*, but slight bluish markings appeared on *A* and *C*. At 140°, slight bluish markings were noted on 1 and 2, whilst the "dimming" effect on 3 was more marked still. 1 and 2 exhibited slight scaling after treatment with steam. *D*, *E*, and *F* showed less marking at 140° than *A*, *B*, and *C*.

It will be noted that glasses of Series I. are more attacked by steam than by water, but water is more corrosive than steam on glasses *A*—*F*.

Again, so far as water alone is concerned, glasses of Series I. are distinctly superior to those of Series II. The question arose as to whether or not this superiority was due to a marked difference in the lead oxide content, that is, in general, to considerable difference of composition, or to the effect of the presence of borax. Certainly both causes might operate, but it was relatively easy to determine the influence of borax by adding approximately the same amount as in glasses of Series I. It will be noted that borax does result in a marked all-round improvement, so much so that, with the exception of some of the soda-potash glasses, *D*, *E*, and *F* are not only better than *A*, *B*, and *C*, but are also better than 1, 2, and 3.

Most striking of the results is the effect of using a mixture of soda and potash in equivalent proportions. The durability is superior in every case except in the hydrochloric acid action on glass *B*. When borax is introduced into glass *B*, its resistance falls into line with all the other series of results. Very remarkable are the results for the soda-potash glasses of Series I. One might expect with the mixed soda-potash glasses to obtain properties approximately midway between those of soda and potash. Evidently such an assumption cannot be justified. We have also found other respects in which the soda-potash glasses containing the alkalis in equivalent proportions are noteworthy, and we are making a similar study of lime-soda-potash glasses.

Evidently the qualities of some of the hard, heat-resisting Bohemian glasses may be connected with their mixed soda-potash content, and it may be remarked that the first effective resistance glass which was developed by Stas for chemical purposes more than fifty years ago contained silica and lime with soda and potash in equivalent proportions. Such a glass was found, not only to be superior to other glasses tested, but could also be founded without serious difficulty.

Summary and Conclusions.

1. Three series of lead-soda, lead-potash, and lead-soda-potash glasses of commercial value have been prepared and tested.

2. The lead-soda glasses melt most readily, the lead-potash least readily. The lead-soda-potash glasses with soda and potash in equivalent proportions fine more readily than either of the others.

3. The lead-potash glasses are the most viscous and the lead-soda least.

4. The colour of the glass due to corrosion on the pot is most marked in the case of the soda glasses and least with the lead-potash.

5. Some lead glasses are more readily attacked by steam than by water. This does not apply to the British full crystal glasses.

6. The presence of about two parts of borax per 100 parts of sand in the batch exercises a notable beneficial effect on the durability of lead glasses.

7. Soda-potash glasses in which the soda and potash are present in equivalent proportions are much more durable than either soda or potash glasses, and a mixture of alkalis is preferable to either for all-round purposes.

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Discussion.

The **President** having invited contributions to a discussion,

Mr. E. A. Coad-Pryor asked whether the tests had been repeated more than once on each piece of glass.

Dr. Turner said that each sample of glass was subjected only once to the test. Obviously if treatment in the autoclave affected the surface of the glass, sometimes causing pitting, a second treatment could scarcely be said to be comparable with the first, in which a clean, undecomposed surface was available.

Mr. J. Northwood said that the results were of very considerable interest to him and to the Stourbridge manufacturers. Some he could confirm from his own experience. He was particularly interested in the advantage of the soda-potash mixture, and he inquired if substitution of part only of the potash were an advantage.

Dr. Turner, in reply, said the durability appeared to increase to a maximum when the equimolecular mixture of soda and potash was reached. Most likely substitution of part of the potash only did result in an improvement even if less than half were replaced by soda.

Mr. Butler referred to personal difficulties he had had. Since the war there had been a greater measure of exchange of ideas than ever before. He paid a tribute to the Department of Glass Technology, Sheffield University, as the place to which they could take their difficulties and get help.

X.—*The Density of the Soda–Lime Glasses.*

By S. English, M.Sc., and W. E. S. Turner, D.Sc.

The density of a glass is by no means an unimportant property to the glass technologist, quite apart from its interest to the scientific worker. In the first place, the waves and cords seen in unsuccessfully founded glass correspond with portions of slightly different density, as also the striæ in samples of unsatisfactory optical glass. Secondly, the density of glass in the fluid state is of importance since the strength of the containing vessel must be sufficient to bear the thrust of the glass in it. Lead glass, as is well known, is relatively heavier, that is, denser, than lime–soda glass, and at high temperatures when the pot softens will be more effective in bringing about bulging at the bottom and sides than the less dense lime–soda glass. Finally, of importance for optical purposes, the refractive index rises steadily with the density, not only in any one series of similar glasses, but in those also containing quite different constituents. Thus, the flint glasses, whether of lead or of barium, have both high density and high refractive index.

On the ground of scientific theory, further, the study of density is of interest as a test of the additive character of this property for glasses, and has also been applied as a means of determining the presence of compounds forming during the fusion process.*

In the determination of the density of glass there are two points to be borne strictly in mind. If the method adopted is the usual one of weighing immersed in water, previous knowledge is required of the extent to which the glass undergoes solution or corrosion. Wherever corrosion by water is appreciable, some neutral liquid, such as pure toluene or pure benzene, must be employed. Neglect of this precaution may lead to erroneous results.

Further, we have found that accurate determinations of density require that the glass shall be thoroughly annealed. In a subsequent paper we shall discuss this subject in greater detail.

For the purpose of our investigations, therefore, the glasses were crushed and sieved carefully, and the portions between 10- and 30-mesh taken for use, a careful selection of the particles being made. This selection was done partly to eliminate particles which might contain very fine seeds and partly because the glass in this state of subdivision can readily and thoroughly be annealed. For the last-named operation it was placed in a hard glass tube, heated to the annealing temperature already known * and allowed to cool very slowly. Ten grams approximately of the powder were then immersed in pure toluene or in water in a specific gravity bottle, all air entangled being removed by reduced pressure, and the density determined at the constant temperature of 20°. Glasses 1—5 were those immersed in toluene, the remainder in water.

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* Tillotson, *J. Amer. Cer. Soc.*, 1918, **1**, 76.

The following table contains the results of the measurements, together with calculated densities based on Winkelmann and Schott's factors.

These investigators concluded that the density of a glass could, very approximately, be regarded as additive, and be calculated from the formula

$$\frac{100}{D} = \frac{p_1}{d_1} + \frac{p_2}{d_2} + \frac{p_3}{d_3} + \ldots .$$

where D is the density of the glass, d_1, d_2, d_3 . . . the densities of the oxides as they exist in the glass, and p_1, p_2, p_3 . . . their respective percentages. The values of d_1, d_2, d_3 . . . are not the densities of the oxides in the free state, but in an assumed condensed condition, the values being quite empirically determined. The values of d_1, d_2, and d_3 . . . are, according to Winkelmann and Schott, SiO_2 2·3, Na_2O 2·6, and CaO 3·3.

Glass No.	CaO per cent.†	Density observed at 20°.	Calculated density.
1	—	2·4353	2·383
2	1·57	2·4384	2·383
3	2·63	2·4416	2·389
4	3·79	2·4462	2·391
5	4·54	2·4507	2·401
6	6·22	2·4602	2·419
7	7·56	2·4650	2·418
8	8·15	2·4682	2·413
9	9·26	2·4757	2·419
10	10·40	2·4840	2·429
11	11·63	2·4904	2·431
16	18·06	2·5866	2·523
17	17·35	2·5547	2·490

† For full composition, see this JOURNAL, Trans., 1919, **3**, 227.

The densities of glasses 1 and 2 are very distinctly higher than those quoted by Tillotson in his paper.‡

The results prove that substitution of soda by lime in a glass brings about a rise in density, and on plotting the results the density was found to be, approximately, an additive function of the composition. Further, Winkelmann and Schott's density factors lead to calculated results much too low, and obviously require revision. We shall return to this subject in a subsequent paper.

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* This JOURNAL, Trans., 1919, **3**, 125.

‡ *J. Ind. Eng. Chem.*, 1912, **4**, 246.

Our thanks are due to Capt. J. R. Clarke, M.Sc., for carrying out a considerable amount of preliminary work on this subject.

DEPARTMENT OF GLASS TECHNOLOGY,
THE UNIVERSITY, SHEFFIELD.

XI.—*The Preservation of Glass Furnace Refractories by Water-cooling.*

By E. B. CHRISTMAS.

(*Read at the Sheffield Meeting, February* 18*th*, 1920.)

It is very many years since it was first recognised that the useful life of any furnace used for a purpose requiring great heat was limited by the progress of the art of brick manufacture.

The natural cooling or preserving agent was water, but it has been a slow process teaching furnace users that a water-cooled device is not necessarily a dangerous one.

The first application was water-cooled castings, and these applied mostly to open hearth furnaces for melting steel. Unfortunately, castings crack, and the trouble and expense of replacing them has in the past caused numerous firms to discard water-cooling, with the result that it is easy to come across men, both employer and employee, who wave aside any suggestion to try water-cooling with the reply, " No, thank you; we tried that years ago." Really the fault did not lie with the idea, but with the application, or, in other words, with the use of castings. In a few cases the tendency for the castings to crack has been lessened by special design and composition of the metal; but even then the economy of brickwork has not been fully effected, as the casting has to consist of metal so thick that the transference through it of the cooling effect is very slight.

The very earliest attempt to prolong the life of refractories was in connection with blast furnaces, and it was quickly evident that it was possible to increase greatly, not only the size and production of the furnaces, but also the life of the lining. It also cut down the loss from frequent repairs.

The fact that the water cooling of gas producers has not proved an advantage in every case has been due to the wrong method of application, and not to the idea. It is the brickwork which requires to be preserved, and therefore water-cooled, and not the fire inside the producer.

About the year 1900, L. L. Knox, of Pittsburg, U.S.A., who had had a good experience of open hearth furnaces, began the study of water-cooled equipment, and has since devoted most of his time to this important subject. Like others, he did not at once light on the real solution. For example, whilst he experimented with steel and iron castings, copper castings, and even plates, shaped and bolted or riveted together, it seems that it was not until about 1909 that he finally turned his attention to welded steel-plate devices.

The value of Mr. Knox's study is seen nowadays in the fact that probably 90 per cent. of the open hearth furnaces for melting steel in the U.S.A. have Knox pressed and welded steel plate devices for the preservation of the refractories, and in fact the name "Knox" and that of the firm bearing his name, "The Blaw-Knox Company," are as familiar in the iron and steel trades in the U.S.A. as are the names "Bessemer" and "Siemens" in this country.

These devices are made in all manner of shapes, and are installed also on heating furnaces, soaking pits, copper furnaces, puddling furnaces, glass melting furnaces, and electric furnaces.

It must be remembered that it is not the object to water-cool steel; it is not the object to water-cool gases. The whole object is to water-cool and preserve refractories. If the most troublesome part of a furnace is first taken care of, then the next most troublesome, and so on, the run of that furnace is lengthened, the output increased due to absence of stoppages for repairs, and the cost of maintenance falls.

My object in first making reference to a steel melting furnace is because it is so similar to a glass-melting tank, and it can be proved that these devices have been used for years on such furnaces throughout America, and for a shorter period in Great Britain and Europe generally.

I will first, but only briefly, refer to the port block frame, one at each end of the furnace hearth, as the usual design of the ports of a glass tank is somewhat different, and we shall come to glass tanks later. This port block frame is simply a tank, or box, made of thin steel plates, without a rivet, bolt, or leakable joint of any description, and the tank is practically entirely buried in brickwork.

The gas and the air meet at the nose of the port, combustion takes place, and the hot spent gas, or gases, after passing over the steel, or glass, in the hearth, strikes against the nose of the port at the exit end and tends to destroy it. So much is this so that when a furnace is first put in commission, the nose, if made only of brickwork, has been built purposely too long, and therefore the gases do not strike the material in the hearth in such a way as to get the fastest working result out of the furnace. The nose gradually gets shorter, as already indicated, until it reaches the fastest working point, and it is this point which the Knox port block frame holds.

The nose, if of brickwork only, continues to burn back until the furnace slows down to such an extent that the nose must be rebuilt; not only for the reason stated, but also because the gases strike against and ruin the roof of the furnace. Then the sequence of events is repeated.

If a water-cooled frame is used, the furnace can be made to work at its calculated fastest working rate from the time it is first put into commission until it is shut down for some other reason, such as repairs to the regenerators.

The outgoing gases strike against the wall of the downtake, which not only tends to affect the life of the furnace and cost of repairs by the destruction of the wall, but also increases the accumulation of dust in the dust chamber below and in the regenerators. This is overcome by embedding in the brickwork Knox water-cooled bulkhead coolers, some of which are put in the back wall only, and some also in the side walls of the downcomer. The brickwork, as will be described later, is then held.

Referring to the construction of doors under the Knox system, these consist simply of brick held in a welded steel frame through which water is passing. There are hundreds of these in use, and they last for years, and without that continual rebricking necessary with dry doors.

Probably the most troublesome part of an ordinary gas-fired furnace is the brickwork round the doorways, or, in fact, round any opening. The water-cooled door is therefore backed by a water-cooled door-frame. The brickwork behind it will become thinned down to about 6 inches, or even to 4½ inches, and will then suffer no further reduction. The week-end patching of the brickwork of the jambs and the arch of the doorway is entirely done away with. Hundreds of these door-frames are in use, there being more than one hundred in Great Britain.

The thickness of the plates varies from ¼ inch to ½ inch, according to size. These devices are made in Sheffield for the requirements of Great Britain, and have also in a few cases been made for France. The back and front plates are first cut to size and then shaped with dies. Stay bolts or bars, as the case may be, are placed between them, and the water-piping welded in position. The whole is then welded. The position of all the welds is carefully studied in every case. Even the water-pipe sockets are welded.

Means are provided for flushing out sediment, which is a point we shall touch upon again when considering the water supply. The water is always led internally to the bottom portion of any device, and allusion is made later to the care taken against steam- and air-locks.

The art of welding has made such strides of recent years that the weld is as strong as the original plate, but as an added precaution welds are not located where they will be directly hit by the flame if it is at all possible to avoid it.

Adaptation to Glass Furnaces.

My endeavour so far has been to show and to describe devices which have been used for years, and fully proved, on steel melting furnaces, which require greater temperatures than glass tank furnaces. Allowing for superheat in each case, and to be on the safe side, an extra temperature of, say, 400° must be allowed for in the hearth when providing these devices for a steel melting furnace in excess of that for glass melting furnaces. Further, the abrasive, or washing, action of molten steel is as injurious to refractories as is that of molten glass.

Although in what follows it will only be possible to refer to glass-melting operations, our remarks also apply practically to lehrs and to any heating operation connected with glass, bricks, copper, pottery, and metals.

The troubles and worries of the glass manufacturer are many and chronic, and the difficulties encountered with the refractories by no means least. To be able to maintain the industry in this country in the future, glass tanks will have to operate longer between each rebuilding, and with as few repairs as possible during the operation, in order to produce a greater output. Increased production and elimination of hot settings and premature repairs can be effected simply and economically by installing these patent water coolers. They undoubtedly bring about increased life of the blocks, eliminate materially the number of hot settings and repairs and the throwing of stones, and cause a general improvement in the working conditions of the tank.

The cooling action penetrates into the blocks for about 6 inches and keeps the blocks from being reduced to a thickness less than about 4½ inches. As the blocks wear down to this point, the slight chilling effect experienced as far as 6 inches inwards from the outer wall will form a thin insulating layer, thus protecting the blocks from the various actions of the molten glass. It is possible to continue to operate the tank regardless of the thickness of the blocks. Should the blocks for any reason wear through (this is very important), the coolers act as a barrier, and the glass coming into contact with the cooled surface freezes, forming a wall of glass.

The object of the coolers is therefore evident. It is to equalise the life and action of the vulnerable, or weak, portions of the tank with that of the remainder.

It was a natural consequence that the advantages obtained by the long life of these devices on steel melting furnaces and the resulting avoidance of the breaking down of a wall, or of refractories generally, should cause the owners of the patents to turn their attention to glass. They found, however, a different set of conditions to fulfil. Moreover, they found that opinions differed as to which was the weakest part of a glass tank. Some owners said the division wall, others the dog house, or, again, the side walls, and so on. But that there were weak parts, which limited the length of life which could be obtained from every other part before a repair was necessary, was very evident.

That this was and is so is shown by the fact that many glass works in America have already installed these Knox devices, and various firms in Great Britain have now got them on order.

Fig. 1 shows a model of a glass melting tank of the open hearth design, fitted at all vulnerable points with water-cooled devices.

No air under pressure is required to aid the water, and therefore the cost of fans, air ducts, and motors is saved, as is also the continuous cost of electric current. Against this, of course, these devices cost money (which, however, especially with a new tank, is partly balanced by the thinner brickwork usable); they require water piping, and the water itself is seldom obtainable for nothing. The water, however, when possible, should be afterwards used for feeding boilers, or for gas producers and water-cooled gas reversing valves.

Possibly the bridge wall may be selected as the part most requiring its life being extended. Fig. 2 is an illustration of a bridge wall tank equipped with water-cooled appliances at the side flux blocks, throat bridge wall, and dog house. The coolers are placed directly against the block and held in place by jack bolts. This design is used by one of the most prominent American glass firms.

We could not have a better illustration to show that these devices do water-cool the brickwork and not the gas or the glass. The brickwork, in the first place, should be built thinner than is

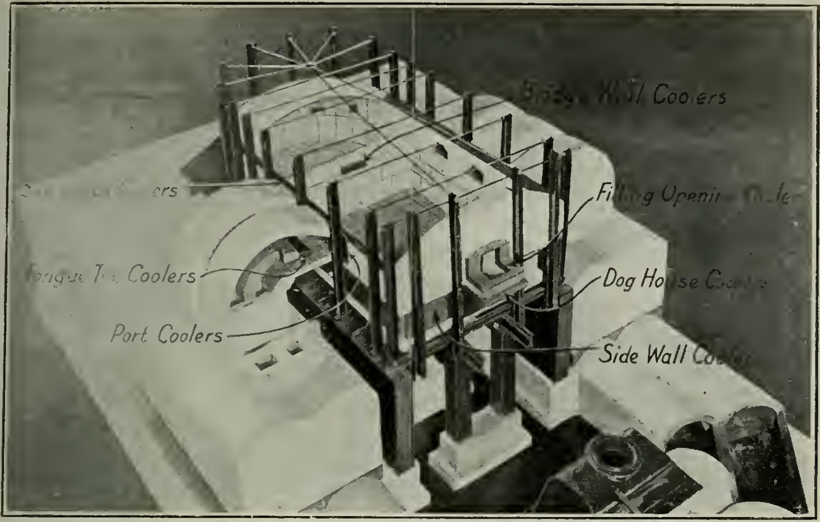

Fig 1.

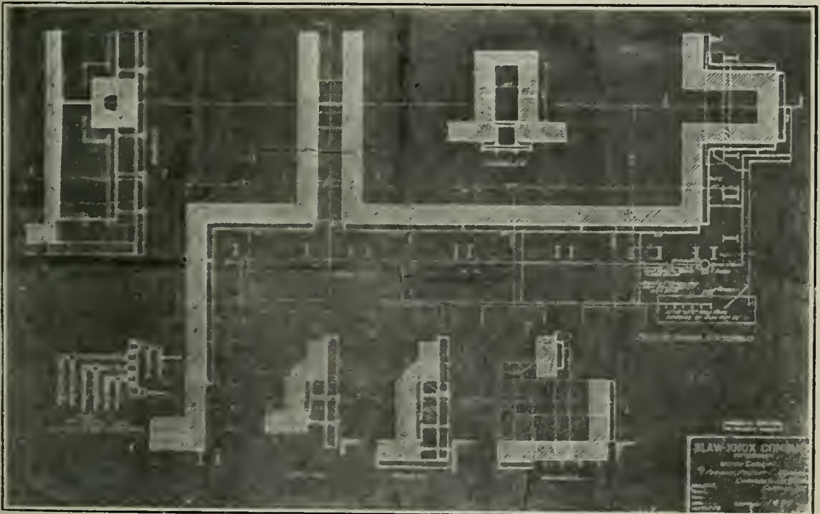

Fig. 2.

[*To face Trans.*, p. 132.

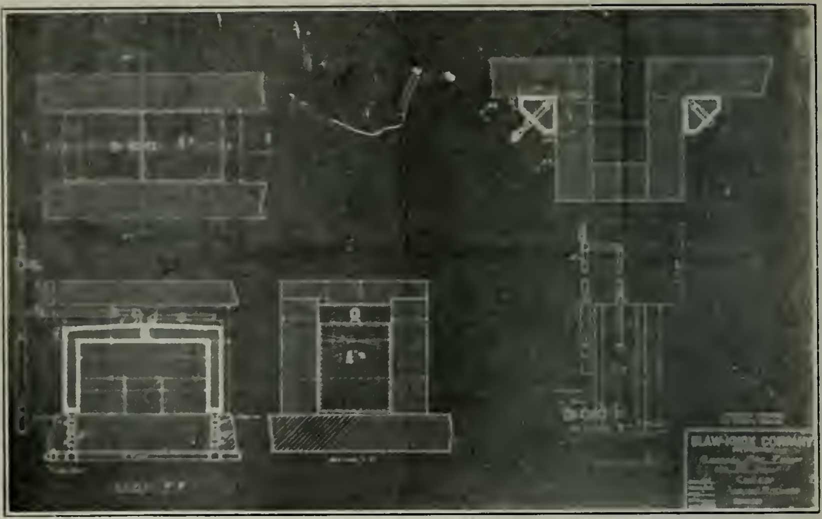

Fig. 3.

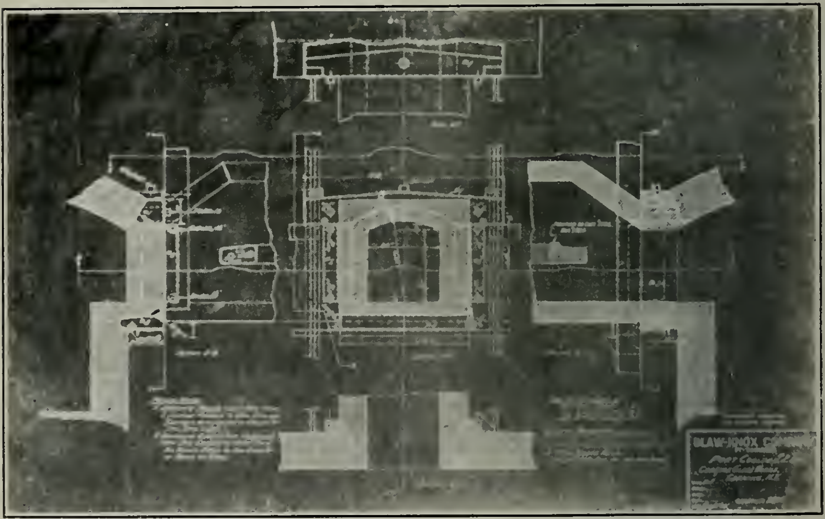

Fig. 4.

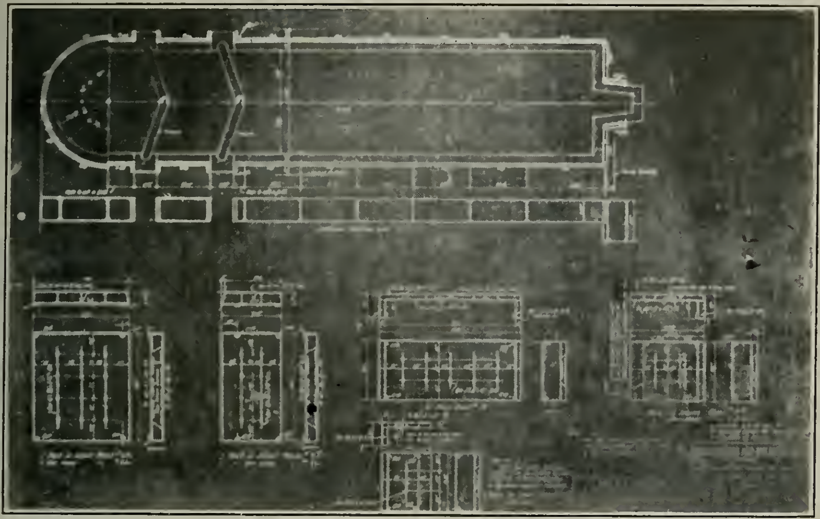

Fig. 5.

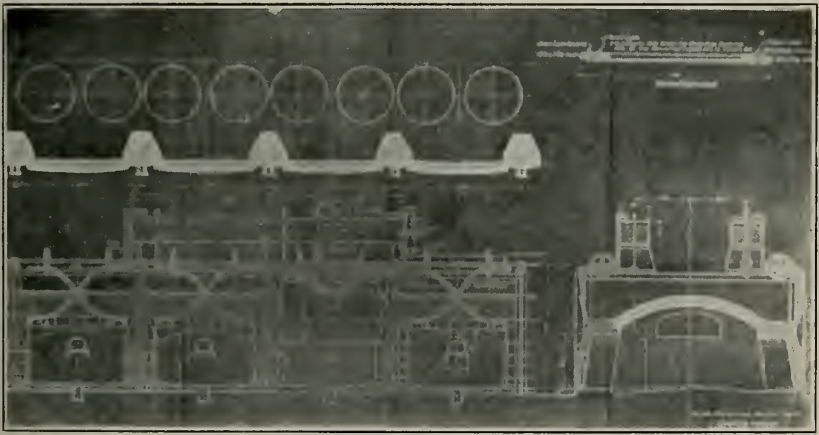

Fig. 6.

the case without a cooler. Whatever its initial thickness, the blocks become reduced until they are only 6 inches or even 4½ inches thick, as already mentioned. By this time, the full effect of the water will make itself felt, the thinning of the brickwork will cease, and the surface of the wall will become glazed.

Until they have seen these devices made only of thin plates, some people fear the possibility of water breaking through to the glass. But if water does trickle through a plate (it probably never will), where will it go to? It will probably find its way down between the cooling device and the brickwork, and not through closely-set brickwork.

Let us take the very worst possibility. Say it trickled into the glass. It would turn instantaneously to steam, and vanish up the chimney stack. I myself have operated any number of charging machines, and tipped gallons of water and wet metal into molten steel whilst the latter was in violent ebullition. Molten pig-iron is brought in large uncovered ladles hundreds of yards through the pouring rain from blast furnaces to the melting furnaces or mixers.

The hole through the division wall, namely, the throat, being water-cooled, retains its size and shape for a very long period, with the natural result that the output of the tank is continued at its maximum, and a larger working run without repairs is obtained until some other portion of the tank gives trouble.

The American firm referred to has these coolers, not only right round the main walls of the tank, but also on all three walls of the dog house. An additional cooler is placed just above the dog hole. The coolers are held in position, close against the refractory block, by any simple device, such as bolts.

Another well-known American firm is now using these division wall coolers on all their furnaces, as they are convinced that, after having used a Knox division wall cooler for more than eighteen months, it is much better than pipe coils or wind coolers. Under normal conditions with wind, the necks needed repairing in about eight months, although they could hold them up to sixteen months. But the first Knox cooler has been working for more than eighteen months without showing any signs of a leak in the neck of that furnace.

Protection of the Dog House.

Coolers for this purpose are put along all three walls. They are generally simply rectangular tanks, properly stayed and held in position. A cooler is sometimes put along the bottom of the dog-hole.

Fig. 3 shows a shortened bridge wall cooler, or what in this case can be called a throat cooler. The water is led in as shown, and released at the top. The cooler at the throat eliminates the troubles generally chronic at this point, and allows continued operation until the tank itself wears out. The dog-house coolers shown are of special design.

An American glass firm, in operating these coolers on one of their tanks, found them so successful that they have twice duplicated them.

Turning back to Fig. 1, it will be seen that coolers are also supplied for the inside of the dog-hole itself, and the batch is thrown straight into, and through, the cooler, without any internal brickwork. This prevents any breaking away of the hole, which retains its shape and size indefinitely. This is quite safe, as will be seen when we come to the gas and air port coolers.

Right round the outside walls of the tank are placed wall coolers. They start at about the flux line, and proceed to a point anything from 9 inches to 4 feet downwards, according to the design of the tank and the number of courses the owner desires to cool. As before, the refractory block will thin down to about 6 inches and then stop. But it would not matter to the cooler if the whole thickness disappeared at places; work would be continued until the day came, when some other repairs had to be carried out.

The great thing to remember is, that thinner walls should be used from the outset. Thick blocks are unnecessary and wasteful. The coolers will give all the protection needed.

Fig. 4 shows the coolers used by the American company previously referred to, to protect the eight gas and air ports of a glass tank furnace. Here we have an example of a cooler which, for the width of the actual port opening, is entirely unprotected by any refractory block, and yet stands up to the tremendous heat and abrasive effect of the hot outgoing gases. Its two extremities are naturally embedded in the side walls for support.

These port coolers, as previously mentioned, make it possible to *build and maintain* the ports at the point where the mixture of gas and air creates the best combustion, the gas being directed and held towards the bath.

The arch-cooler shown entirely prevents the outgoing gases from wearing through at the point where the main roof is connected with the roof of the port. It also acts as a skewback to take the thrust of the roof. It is insulated with only 4½ inches or 6 inches of brickwork, as also are the vertical corner coolers at the joints of the side walls of the ports and the main side walls of the tank itself. In this case a further cooler keeps the floor of the port from wearing away.

A quite natural question asked is, Does not the heat cause expansion, and tend to burst the welds apart, either due to this expansion or to the contraction on cooling down? This is so, but protection from any tendency in this direction is obtained either by corrugations which relieve any strain or by stay bars.

Fig. 5 shows devices on the tanks in the works of an American wire glass company. These have no corrugations, but have bar stays as shown, and as referred to earlier in this paper. The devices are placed all round the tank, which is of the float type. They vary from 4 feet 6 inches deep at the dog house end to 2 feet 6 inches. The firm in question has been using the Knox coolers for nearly three years. The refractory material of the dog house, when it had run about eleven months (it has now run fourteen months) had been worn down to within about 5 inches of the cooler, and it was good for another eleven months. This firm states that before coolers were installed the best possible life of the dog house block was six months. The quality of glass is much better with absolutely no increased fuel consumption

Amount and Character of Water Required for Cooling.

Fig. 6 shows the doors and the water circulating system of a pot furnace. The holes in the doors are also high.

The water reservoir tank is not necessary where water is very cheap and quite trustworthy, but in other cases it is necessary, and in all cases an advantage. Its main purpose is water economy. Only one-third to one-half the amount of water will be wanted for a given number of devices than will be required without a water-tank. The pressure of the new water coming through the jet, or injector, shown, causes the water in the tank to keep circuiting round and round the system, the new water only needing to be sufficient to make up for what has evaporated, or to maintain the temperature of the water in the devices at 180° F. or thereabouts. From the reservoir-tank the water flows through pipes to the bottom, as already described, of all the devices, and then back to the water-tank. The top of the reservoir is open to permit the water to cool. The tank is not always placed, as shown, on the furnace itself, and can be yards away if preferred, but there is no reason for it not being on the furnace.

The second advantage of the water reservoir tank is, as its name implies, the reserve of water in it if the water supply temporarily fails or has to be turned off in the works for a short while.

The third advantage is that of an alarm. If the water supply fails the water in the tank gradually gets continually hotter, and the off-going steam warns the furnace-hand.

The amount of water required will depend on the number and size of the devices; on the condition, size, and type of furnace; on the quality of the water; and slightly on the pressure of supply. When the water contains solids, such as lime, which will be precipitated when the water becomes heated, the outlet water should be kept at about 10° to 15° F. below the temperature at which precipitation would take place. If the water does not contain such solids, the outlet water should be kept at about 180° F.

All the devices are provided with cleaning holes for occasional flushing out. Where very dirty water is used or water containing solids in quantity, these cleaning holes are substituted by a large hand-hole.

Where no water-tank is used, it is preferable to let the out-flowing water drop into a funnel, conveniently placed where the operator can see if water ceases to flow away, as this will indicate that the water supply has failed.

Although it is only sensible to provide these means of ensuring that the water supply has not ceased, it is only fair to point out that in America they seem to look upon a trustworthy water supply as much more necessary than in this country. It is quite common in this country to meet firms who desire, and have desired for years, to instal up-to-date gas producers, gas reversing valves, and these water-cooled devices; but have been held up every time the proposition has cropped up, simply because a water supply installation will cost a large outlay of money. But this country cannot afford to stand still, and besides, if up-to-date inventions pay in other countries, they would quickly pay for a water supply installation here.

Since, from the title of this paper, I have confined myself, as regards the preservation of refractories, to the discussion of water-cooling, it is not my purpose to enter into the question of gas producers, but I may also lay stress upon the quality and regularity of the gas as being as important as water-cooling in preserving the life of a glass tank furnace.

By adopting water-cooled devices, however, no radical change is introduced into the works practice, but only a means of getting longer life from the refractories, thus reducing labour costs and obtaining a greater output per annum.

Finally, but not the least in importance, the efficiency of the workmen about the furnace is materially increased when they are not subjected to the intense heat of ordinary dry-front furnaces.

~~WHITE BUILDING, FITZALAN SQUARE,~~ PRUDENTIAL BUILDINGS,
~~SHEFFIELD.~~ PINSTONE STREET,
SHEFFIELD

DISCUSSION.

Dr. Travers thought that the necessity for water-cooling installations was tantamount to a confession of failure on the part of the makers of refractory materials. At the same time, water-cooling had a remarkable influence in prolonging the life of the furnace blocks. Naturally they all hoped for the time when water-cooling devices would be unnecessary.

Dr. Turner agreed with Dr. Travers in the view that the necessity for cooling devices was an admission that we were yet far from the ideal furnace. Water cooling had been stated to be an ideal method of furnace preservation. He would like to urge that the word "ideal" should scarcely be used in this connection or to any system which meant that part of the heat supplied to the furnace was purposely neutralised. Still, until the ideal refractory material was obtained, water cooling was valuable. He would particularly like to refer to water cooling of the working end of a tank furnace, especially one operated by hand. Such furnaces were to be seen in New Jersey, and he had formed the opinion that the water-cooling did materially add to the comfort of the workers.

There was one point in regard to the system about which some doubt had been expressed to him, namely, that some trouble might be experienced if the solidified glass produced on the bridge walls by water-cooling the exteriors should crack and break away. Fear had also been expressed that in the case of water-cooling the throat complete blocking might occur. Finally, he would like to inquire if trouble were found in the deposition of solids from the hard waters natural to some places, such as Ohio and Indiana.

Mr. Connolly asked what quantity of water would be used per twenty-four hours per sq. foot of cooling area. He thought that the fact that there had been a charge of freezing the throat was a demonstration of the effectiveness of the cooling device. He had seen cooling devices in operation in the States, and there was no doubt, as mentioned by Dr. Turner, that the cooled working end added to the production, especially in the hot season. He would also emphasise the advantage of being able to use thin blocks. It was an old-fashioned idea that the block must be 14 or more inches thick, and he had seen blocks used of little more than half this thickness.

Mr. Christmas, replying to Dr. Turner, said the question about the freezing of glass in the throat was put to him about six weeks ago, and he specially wrote over to America for a reply on that very point. The inside surface of the block will tend to be thinned down until it was about 6 inches thick, and then a glaze would be formed over it. Beyond this glazing further freezing would cease; that is the point which had to be grasped. The cooling only penetrated 4½ inches into the brick; therefore, freezing would take place between anything from 4½ to 6 inches, but would not go deeper.

As regards the water, the proper way to deal with it was to have a chemist in the works. In America, chemists were much more greatly employed than in this country. Every glass works should have a chemist or chemists, and they should find out full particulars of the water used. If precipitation took place at 160° F. then water always should be run off below 160° F., but this was a question for the works itself. The temperature of the water, of course, depended on the point of formation of the precipitates.

The question of the quantity of water used was a very hard one. Sometimes one could find but very little to indicate how much water was used on a glass plant. Conditions varied so greatly that one had to come down to an approximate figure. Four to five gallons per hour per sq. ft. of cooling surface might be assumed. Naturally the position of the tank would make a great deal of difference. If in a draughty position it required less water than otherwise.

XII.—*Note on the Tensile Strength of Refractory Materials.*

By MORRIS W. TRAVERS, D.Sc., F.R.S.

WHILST a considerable amount of attention has been paid to the investigation of the resistance to crushing of refractory materials, and crushing tests are included in many specifications, I have not been able to find any references to measurements of the tensile strength of refractories. The matter is of importance, for in modern glass furnaces, working at high temperatures, failures are generally to be attributed to the fact that the materials are in tension rather than under load. I propose to illustrate this fact by means of a few examples.

The pillars of a recuperative pot furnace are usually built of single blocks, in the form of a truncated V, and measuring approximately 2 ft. by 2 ft. by 6 in. to 9 in. The blocks are built into the furnace, so that, while the top of the V is air-cooled, the truncated point is at the highest temperature of the furnace. As the latter is higher than that at which the blocks are, or can be, burned, it is generally found that when the furnace has been in action for a few days a considerable shrinkage has taken place, and the joints between the blocks have opened out. The inner portion of each block now projects into the furnace, unsupported from below, with the result that horizontal stresses are set up in it, the upper layers being in tension, the lower in compression. After a short time cracks appear in the upper surface of the blocks, and large pieces begin to fall away from them. The upper blocks are usually the first to suffer, partly because they receive less and less support from below, as the destruction of the pillar proceeds, and partly because they are subject to the action of the hot gases before they have been partly cooled by contact with the pots.

On several occasions I had the opportunity of studying a type of furnace in which the air and gas meet in a channel, or eye, of comparatively small cross-section, at a considerable depth below the siege. In this furnace, no matter how it was handled, combustion took place, and intense heat was generated, deep down in the channel. As the result of the shrinking of the brickwork below the siege blocks, the latter were, after the furnace had been at work for a very short time, unsupported at their edges, with the result that they began to fail in the same manner as the pillar blocks. The parts of the siege around the eye first took a downward slope; vertical fissures developed in their upper surfaces, and finally large pieces of the siege blocks became detached and fell down the eye.

The bursting of glass-pots in furnaces which are worked at high temperatures, when the temperature has not been dropped as soon as the metal was plain, is due to the tensile strength of the material falling, with rise of temperature, below that at which it can withstand the pressure of the molten metal.

The ratio of the numerical values of the tensile strength to the resistance to crushing stresses for materials such as stone and marble is about 1 to 20. But in the case of refractory materials at high temperatures we are almost invariably dealing with a structure composed of solid particles in a glassy matrix. By solid I do not mean the grog which is used in the manufacture of the refractory. The differentiation of grog and bond clay concerns only the process of manufacture; for when the material has been subjected for some time to a high temperature, grog and bond material cease to be distinguishable. This we may attribute to diffusion, which takes place to a very appreciable extent at temperatures far below the softening points of materials. By solid I mean insoluble, crystalline material which is present in the refractory before it is burned, or which is formed *in situ*. The tendency to squat is decreased, and therefore the resistance to *viscous* compression increased, by the addition of finely divided solid material to the refractory, probably in accordance with some law analogous to that of Stokes. I do not think that the same procedure would necessarily increase the tensile strength of the material. Again, the view put forward by R. C. Purdy that the ideal refractory consists of a high percentage of very infusible material, carefully graded, and bonded with a very small quantity of vitreous bond, may be justified when applied to refractory materials designed to withstand crushing load, but it does not follow that they will withstand tensile stresses equally well.

The ideal refractory consists of a system of interlocking crystals, formed *in situ*, in a glassy matrix. If the matrix is such that it forms a *sillimanite* layer in contact with alkaline fluxes, corrosive attack by glass may be largely discounted. The *sillimanite* layer appears to be sufficiently impervious to delay, very considerably, the mixing of the liquid phases on either side of it.

The problem indicated is one for experimental investigation.

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XIII.—*The Casting of Pots for Use in Experimental Work on Optical Glass.*

By Alice B. Taylor.

Introduction.

Casting has been found by certain manufacturers to be a good method for making glass pots, but it requires to be carried out with a specially prepared clay body. This is due to the fact that the ordinary glass pot as required for use by the glass-maker has a thickness of wall amounting to 3—4 in. With a non-uniform material, such as a mixture of clay and finely ground fired ware (grog), the segregation of one of the constituents into bands or layers is very likely to occur in a pot of this thickness. Consequently, the casting process for glass pots is not so universally employed as that of hand-moulding.

In order to cast a mixture rich in grog—which is the chief advantage belonging to the cast pot, as opposed to that moulded by hand—the proportion of water added to the clay should be about 20 per cent. A small quantity of an alkali or of an alkali salt is generally added, usually in the form of sodium carbonate or sodium silicate, and the amount varies, according to the user, from 0·2—0·3 per cent. by weight of the dry body. The action of the alkali is to cause complete suspension of the finer particles of the clay, to prevent coagulation, or flocculation, as it is called. Hence the alkali is generally termed the deflocculator. Its presence greatly facilitates the casting process.

Bleininger says: "Alkalies tend to hold the clay in suspension in a fine-grained and jelly-like mass; acids and salts operate to coagulate and precipitate the material. Clays suspended in water are affected by the presence of small amounts of these substances to a remarkable extent. By the addition of alkaline compounds, the amount of water required is decreased very greatly, and with it the drying shrinkage." *

For usual casting operations Bleininger used a mixture containing 47 per cent. of clay, 48 of grog, and 5 of felspar. The latter during the casting is without plasticity and behaves, while suspended in water, as finely ground grog. The slip when made up carries 80 per cent. of solids, and hence 20 per cent. of water. The weight of the deflocculator in terms of the dry weight of the body is 0·2 per cent.

The mould into which the slip is poured is made of plaster of Paris. It consists essentially of an outer case and an inner core, both of plaster, between which the slip is poured. In his report on the making of special pots for the melting of optical glass Bleininger gives the following description:—

"It is necessary to hold the core (of the mould) firmly in position by means of cross-beams and tie-rods, as the upward hydrostatic pressure is very considerable. The casting, as now practised, is through three funnels arranged symmetrically around the circumference of the mould. The liquid in the funnels is replenished as the level of the liquid is lowered. Absorption of the liquid ceases after about sixteen hours, and the core can then be removed. The mould can be taken apart after twenty-four hours. The preparation of the slip is very simple, and consists merely of introducing the weighed, ground body constituents into a double blunger together with the required amounts of water, in which the sodium salts are dissolved. When the proper consistency has been attained, the slip is allowed to run into a large bucket, which is conveyed to the mould. . . . No difficulty has been experienced in drying the cast pots in three weeks. They have given very good satisfaction in the glass furnaces, and, if anything, are superior to the hand-made ones." †

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* Bur. Stand. Tech., Pap. No. 51, Sept., 1915.

† "Special Pots for the Melting of Optical Glass," A. V. Bleininger, *J. Amer. Cer. Soc.*, 1918, **1**, 15.

The advantages of casting compared with modelling or hand-moulding appear to be the following:—

1. A thorough mixing of the ingredients is possible without the expenditure of much labour.

2. A larger proportion of fired material (grog), and therefore a smaller one of clay, can be used, with consequent increase of refractoriness of the pot and resistance to sudden changes of temperature.

3. Skilled labour is not required.

4. The time occupied in the production of a pot is very much reduced.

5. The cost of production is consequently decreased. The process is very simple, but it is true that it requires adaptation to each mixture, some clays requiring more attention in this respect than others.

Object of Present Experiments.

The experiments on pot casting were undertaken because it was desired to maintain a supply of pots of suitable shapes and sizes for experimental meltings of optical glass. It was therefore necessary to study the methods by which these pots could be most satisfactorily produced, and the work thus undertaken has led to the adoption of a method of casting in plaster moulds under considerable pressure. This process has proved most satisfactory for the pure kaolin which it has been necessary to use.

The problem requiring solution was the production of a sound kaolin pot with a slight taper and open at the top. The size (height, 9 in.; diameter of top, 7 in.; thickness, $\frac{1}{2}$ in. at top, $\frac{3}{4}$ in. at base) was, of course, much less than that used commercially.

The material from which the pots were to be made consisted of a mixture of china clay and grog (fired to cone 18) in the proportions 3:2. The grog, previously freed from iron by magnets, consisted of particles which had been passed through a sieve having 20, and in some cases 30, meshes to the inch. To this body, sodium carbonate (one-eighth per cent. of the total dry weight) and sodium silicate (one-eight per cent. by weight of the clay content) were added in solution, the resulting weight of the two salts being about 0·2 per cent. of the total dry weight. The whole was thoroughly mixed with a thick slip and allowed to stand.

First Experiments.

The first method tried was that of simple slip casting. The mould consisted, as in the Bleininger process, of an outer case and an inner core, both of plaster, between which the slip was poured. The core, made in one piece, was removed directly the pot had set, thus allowing for contraction of the clay on drying.

In the first experiments, the slip was poured in between the core and the mould, and the core was suspended from a bar resting upon the outside mould, as in Fig. 1.

The pots obtained were usable, but were not free from holes, the difficulty being that if the slip were thick, air bubbles were entrapped at the base, while if the slip were thin enough to prevent this, a partial separation of grog and clay took place, grog being more plentiful in the lower layers of the bottom of the pot and down the centre of the sides. Fine particles appear to be drawn towards the walls of the mould more easily than coarse, and the central portion of the pot is the last to solidify.

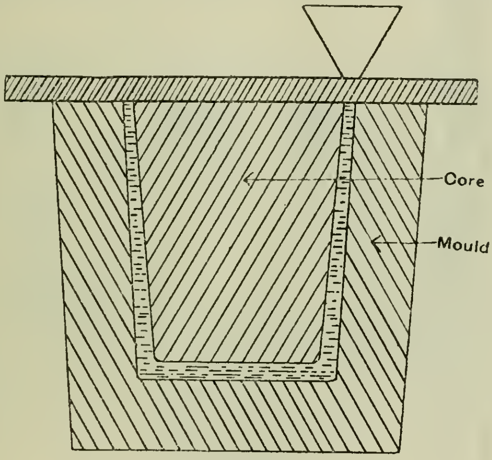

FIG. 1.

Several pots were cast in this manner and used. They all contained flaws. Some showed a tendency to crack on drying and subsequent firing, probably because the distribution of clay and grog was not uniform. This lack of uniformity is shown in the sections illustrated in Plates 1 and 2. It was therefore decided to force the slip upwards through a hole in the base of the mould. This would, it was hoped, eliminate the difficulty of air-locks and give a more uniform body.

In the next arrangement tried, the clay entered the mould under pressure of a head of slip. For this purpose, the slip was poured down a flexible tube connected to the base of the mould. A funnel at the further end of the tube was kept supplied with material, and could be raised and lowered at will. After filling, the surface of the clay in the mould was kept at a constant level by adjusting the height of the column of liquid. This method is shown in Fig. 2.

The surface of the pots cast in this way was good. It was, however, soon found that they possessed a tendency to develop a ring-shaped crack around the inside of the bottom, and a section showed the structure as sketched in Fig. 3. The pot photographed in Plate 3 is an example.

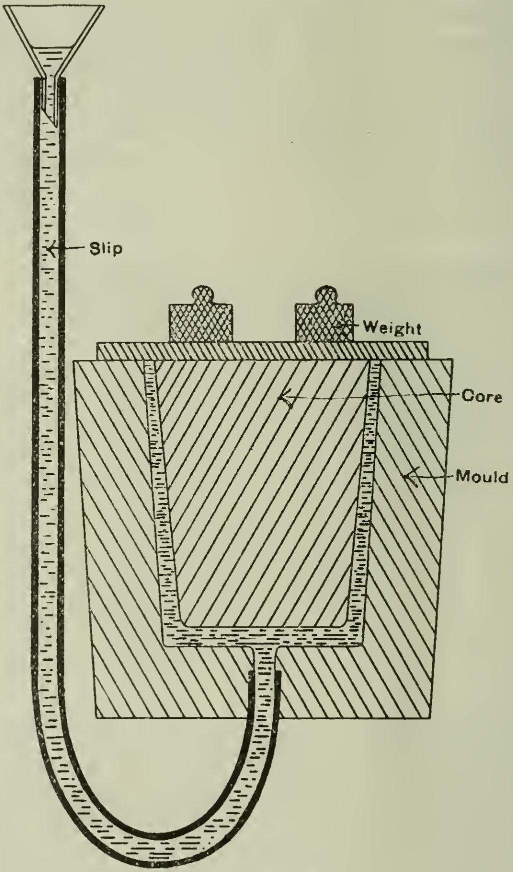

Fig. 2.

The distribution of clay and grog in the sides was fairly uniform, but this was not the case in the bottom, and the clay belt there deposited on the core was prejudicial to the safety of the pot on burning.

Two remedies for this defect were consequently tried.

1. Previously wetting the core. This was not satisfactory.
2. Passing an electric current between core and mould.

For this purpose, the mould and core were connected with a direct-current circuit (110 volts), the mould constituting the anode and the core the cathode. An experimental series of pots was cast. These were all broken up for examination.

In the first two cases the current had been maintained during the casting of the pot and until the slip had set. The current passing was very small (less than 1 amp.), but it was sufficient to decompose the electrolyte, and a band of bubbles appeared. These are seen in sections cut from these pots, as illustrated in Plate 4. The method attained its object in so far that a layer of coarse grog particles was found immediately in contact with the core, but a band of clay and bubbles succeeded this. In some cases the bubbles reached fairly large dimensions (Plate 4).

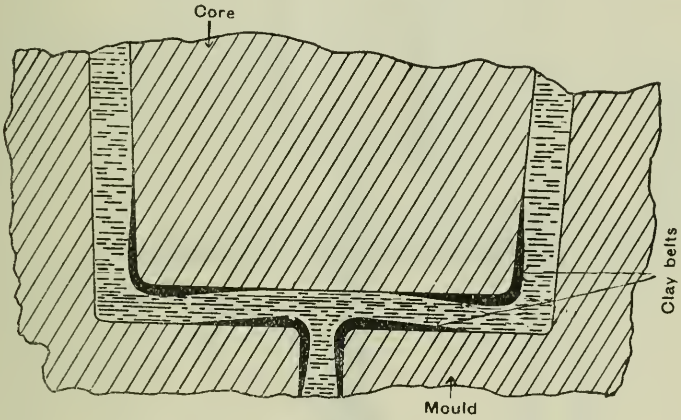

Fig. 3.

If, in order to avoid the formation of bubbles, the current was passed for only short lengths of time (say, one to three seconds at intervals of one second), its effect was so slight as to be negligible.

Casting under Air Pressure

It was thought advisable at this stage to try a more rapid filling of the mould, so as to eliminate the band of clay formed on the core during the time of filling.

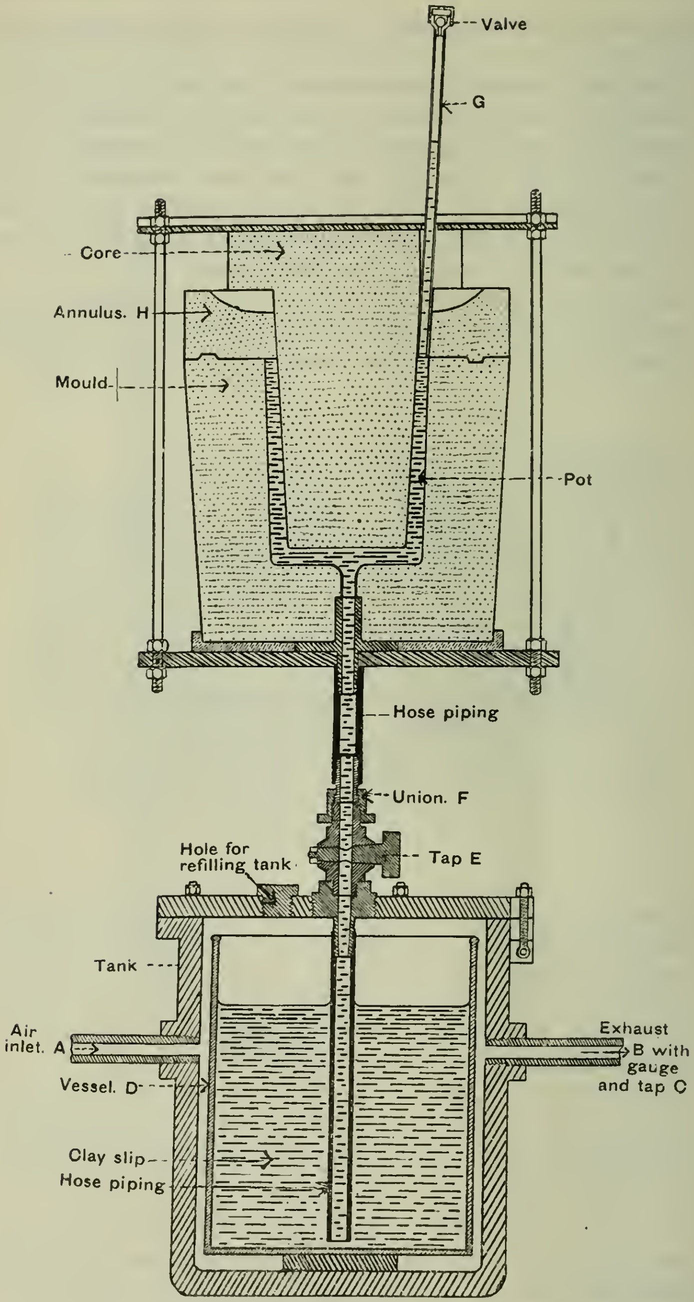
Valve
G
Core
Annulus. H
Mould
Pot
Hose piping
Union. F
Hole for refilling tank
Tap E
Tank
Air inlet. A
Exhaust B with gauge and tap C
Vessel. D
Clay slip
Hose piping

FIG. 4.

Experiments were consequently made on the casting of pots under a considerable pressure. The apparatus used is outlined in the accompanying diagram (Fig. 4). It consists of a cast-iron tank with a well-fitting and removable lid. In the side of the tank is an air inlet (*A*), and also an exhaust pipe (*B*) with a gauge for pressure readings, and a tap (*C*), which can be regulated. Inside the tank is an enamelled pan (*D*) which contains the slip. A pipe, ending about 1 in. from the bottom of the pan, leads up through the centre of the lid of the tank into the mould. This pipe is made, as far as possible, of rust-proof material, since any iron in contact with clay tends to oxidise, and contains a well-fitting tap (*E*) with a union (*F*) just above it, which can be unscrewed when the mould is to be removed.

When the air is turned on, both taps (*C* and *E*) are kept shut, and the pressure is allowed to rise in the tank until a required figure is reached. The tap in the central pipe (*E*) is then opened. The pressure forces the slip up the central pipe, through the mould, and up the exit pipe (*G*) at the top of the mould. The air which is being replaced by slip escapes largely through the pores in the mould itself, but mainly up the exit pipe (*G*) at the top. This pipe ends in a ball valve, of which a detailed drawing is given (Fig. 5). The valve allows air to pass, but not a viscous fluid, so that, when the slip has reached the top, the exit is automatically sealed.

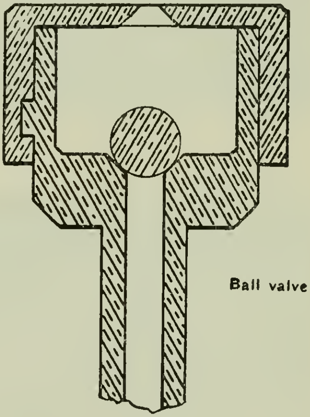

FIG. 5.

The initial pressure required for this size of pot is about 20—25 lb. per sq. in. After filling, the pressure is lowered to about 10 lb. per sq. in. by adjusting the tap (*C*) in the side of the tank. It is kept steady at this point until the pot has solidified. For a smaller size of pot (height, 5 in.; diameter of top, 4¼ in.; thickness of wall, ½ in.) the initial pressure used was 8—15 lb. per sq. in., and the subsequent 5—10 lb. per sq. in., the time of filling being about one and a-half minutes to thirty seconds, according to the initial pressure used. After about forty-five minutes or one hour, the pressure is released, the core is removed by levering it up from the annulus (*H*), and the crucible itself is taken from the mould and set to dry.

The diameter of the entry hole in the mould should, of course, be as great as or greater than the thickness of the widest part of the wall of the pot, in order to prevent sealing up before the pot itself has finished setting, and it is wise to surround the place of entry with a non-porous layer, for example, with several coats of shellac or some thin rubber tubing.

The rate of rise of the slip in the mould is of great importance. Too rapid a rise produces splashing of the slip against the bottom of the core and the inclusion of bubbles, the presence of which can be detected later by means of a radiograph (Plates 6 and 7).

A second ball valve placed in the centre of the bottom of the core has been tried as a remedy, but it was found that this, although advantageous in the elimination of bubbles, was by no means necessary if the right rate of rise was maintained.

The rate of rise naturally depends upon the initial pressure, the resistance of the mould and tubes, and the viscosity of the slip. With the china clay slip used, there are very narrow limits in weight between a thick slip from which bubbles will not escape and a thin slip in which grog will settle. Several slips of different weights and viscosities were made up and tried. The following are examples:—

Weight in grams per litre.		Rate of flow. (Weight, in grams, passing through $\frac{1}{4}$ in. funnel in 20 secs. Height of liquid 6 in. at start).	Time of rise through the mould with pressure 15 lb. per sq. in.
1	1,705	100	2–5 seconds.
2	1,715	50	
3	1,740	38	35–90 ,,
4	1,753	35	
5	1,773	29	

1 gave decidedly poor results.
4 gave quite good results.
3 gave very good results.

The viscosity figures given would in all probability be different for different slips and also for the casting of pots of larger size, where a longer range of viscosity would probably be permissible. It will be seen that for a given mould and initial pressure, the time of rise is a very sensitive measure of the viscosity.

Many pots have been cast by this method. Several have been used in optical glass melts. They are superior to pots cast in the usual manner in possessing a less permeable and more uniform structure. They have so far been satisfactory.

Description of Sections.

Throughout the work on casting, examination of the distribution of clay and grog in the pot was rendered possible by a method

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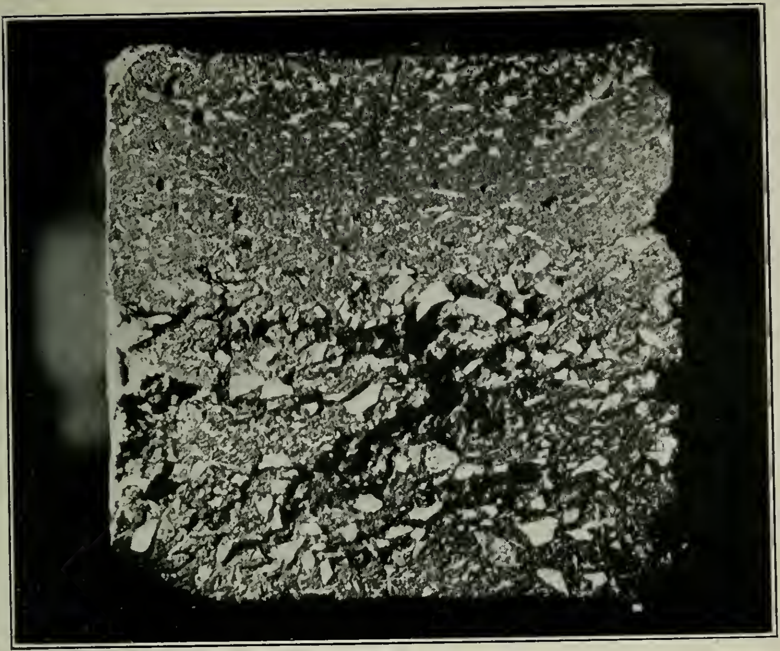

Plate 1.

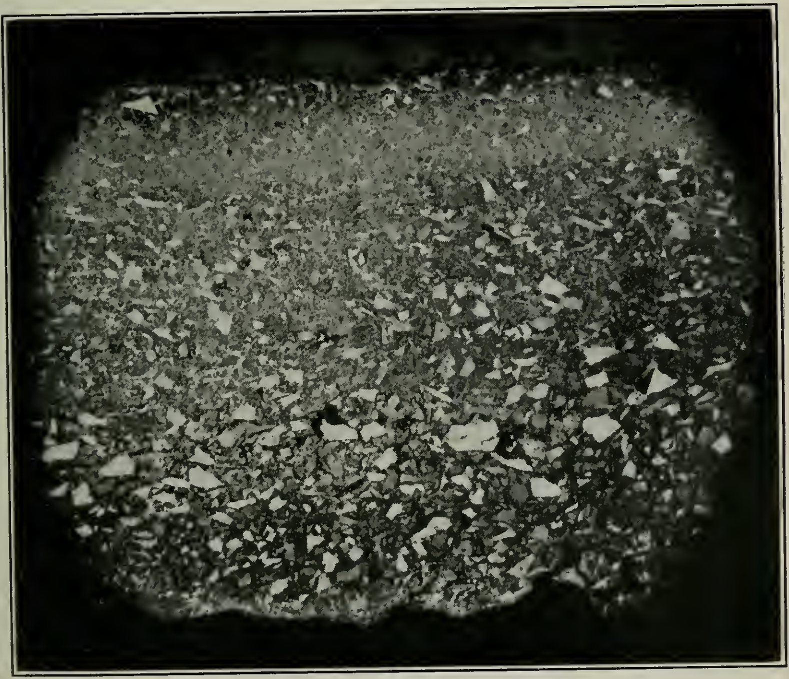

Plate 2

[To face Trans., p. 148.

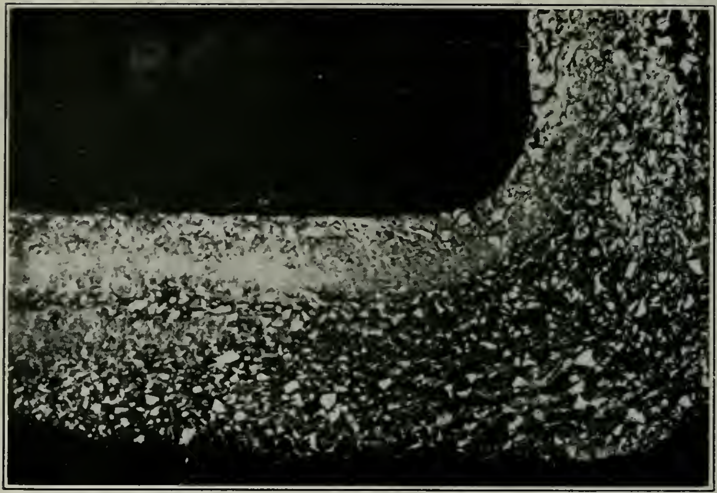

PLATE 3.

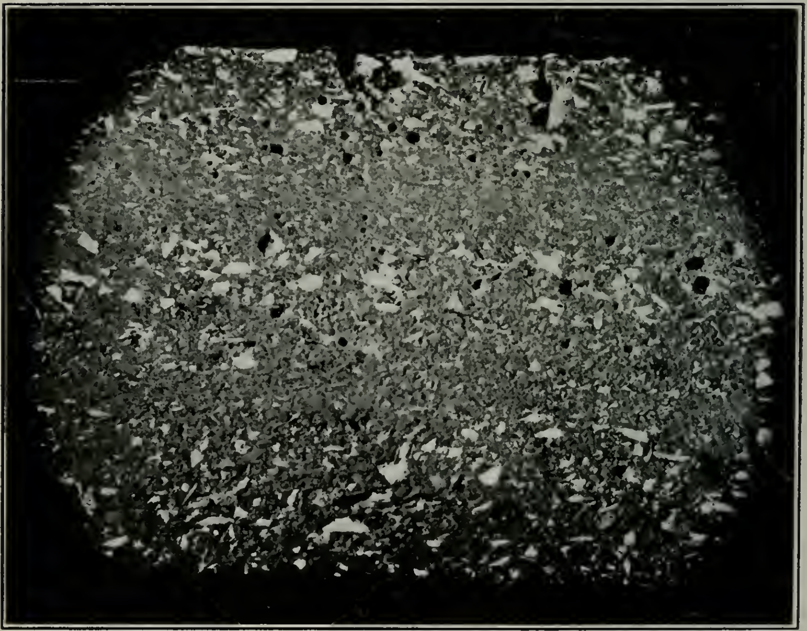

PLATE 4.

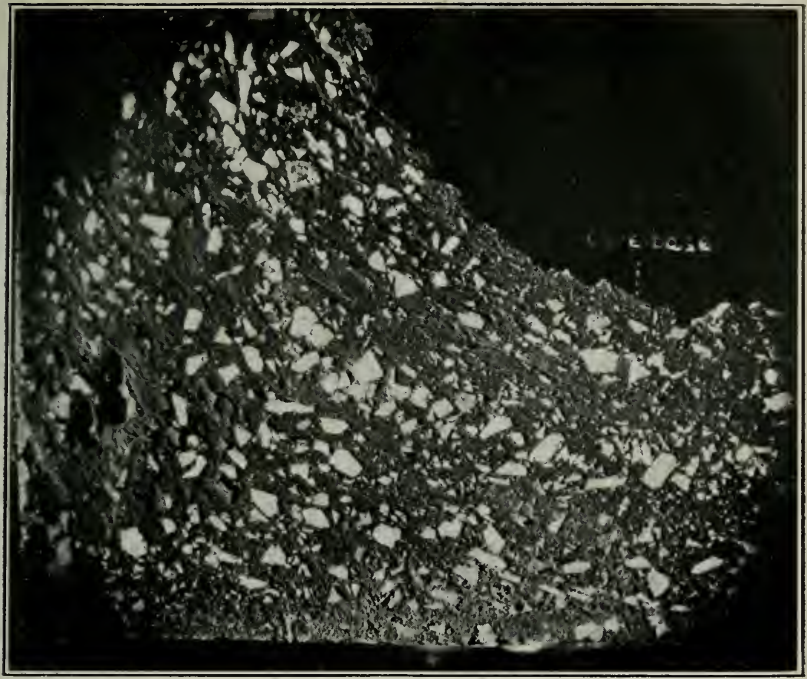

Plate 5.

Plate 6.

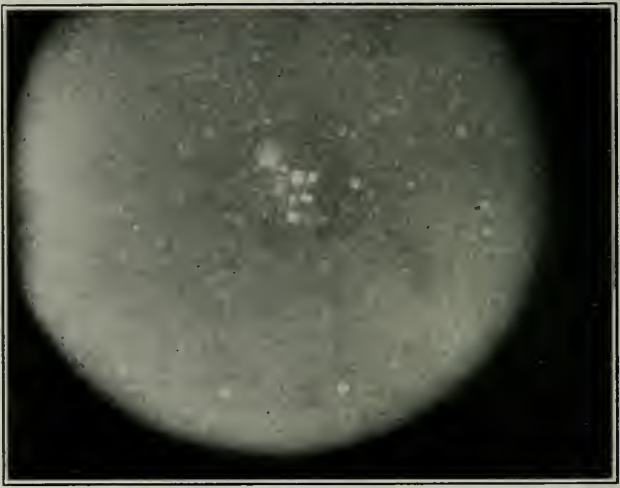

Plate 7.

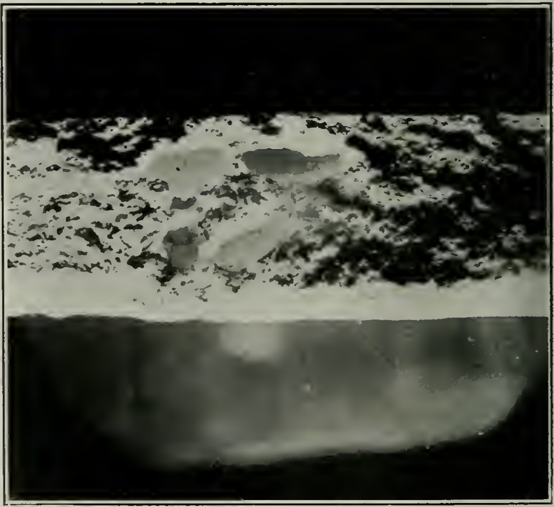

Plate 8.

devised by Mr. E. A. Coad-Pryor. The green pots were thoroughly air-dried, then broken into fragments, which were heated up slowly to about 500°, when they were transferred to the ordinary blowpipe and taken up rapidly to a temperature 100—200° lower than that of the original firing temperature of the grog. These fragments were ground on a carborundum wheel, so as to give a section at some distance from the surface, then on fine carborundum and emery, and finally polished on a pad with rouge.

Care must be taken when heating in the blowpipe that the right amount of firing takes place, for if too high a temperature is maintained, the structure, particularly near the surface of the specimen, may become obliterated and the outlines of the grog particles indistinct when the specimen is polished. On the other hand, too low a temperature is not sufficient to harden the clay appreciably. The grog lumps easily tear out, and the specimen will not polish well.

In some cases in the accompanying photographs, small cracks appear, which are due to carelessness in firing with the blowpipe, and which would not develop in a pot fired in the furnace in the usual manner.

Plate 1.—This section is taken from the bottom of a pot cast under pressure of a head of slip only. It shows a preponderance of grog in the bottom layers. Magnification about 3.

Plate 2.—A section similar to that in Plate 1. A distinct band of clayey material is visible on the side adjacent to the core of the mould. Magnification 3.

Plate 3.—A section taken from the bottom of pot which shows the extension of the clay belt round the corner on the under side. Magnification $1\frac{3}{4}$.

Plate 4.—The pot from which this section was taken was cast with the aid of an electric current continued until the clay had set. In this case the difference of potential was 110 volts, while the actual current, though less than 1 ampere, sufficed to decompose the electrolyte and gave a pot full of bubbles. Magnification 3.

Plate 5.—A corner of a pressure-cast pot, magnification about 3 diameters. Initial pressure 25 lb. per sq. in., subsequent pressure 10 lb. per sq. in. for one and a-half hours.

Plates 6 *and* 7.—Radiographs of pots cast under pressure. The rate of rise of slip had been too rapid, and air bubbles had been entrapped at the base. To the naked eye the pots appeared perfectly sound.

Plate 8.—A section of the pot radiographed in Plate 5, showing holes caused by entrapped air.

Plates 9 *and* 10.—Sections of a pot cast under an initial pressure of 20 lb. per sq. in., with a subsequent pressure of 10 lb. per sq. in. Magnification about 2 diameters. These sections show a very uniform distribution of grog.

In conclusion, I should like to thank Dr. Rosenhain and Mr. E. A. Coad-Pryor for their interest and help in the work, and also A. Hatcher for his assistance in carrying out the experiments.

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Teddington, Middlesex.

[*Received, April* 16*th*, 1920.]

DISCUSSION.

Mr. B. J. Allen (*communicated*).—It was with great pleasure that I read Miss Taylor's communication on the casting of pots, and I can heartily congratulate the author on the work done.

Having had considerable experience in connection with casting slips, I quite realise the difficulties which are encountered when making small mixtures for experimental purposes.

Making slip in bulk for commercial purposes is a much simpler operation than blunging small quantities.

I hope that my comments will be taken in the spirit intended, namely, constructive and not destructive criticism.

With regard to the introductory remarks, the segregation of grog will not take place in a properly prepared slip mixture. I have had occasion during the last few days to run out of a storage cylinder, which has not been disturbed for four months, about a ton of slip made up with clay 50 per cent., grog 50 per cent., alkalies 0·25 per cent., and which, when made, weighed 29½ oz. to one pint. This slip showed no appreciable signs of grog separating.

Manufacturers who use fireclay slips extensively do not experience any serious difficulty on account of the separating out of the coarser material, and some other explanation must be found to account for casting not being universally used for the manufacture of glass pots. Personally, I am of the opinion that manufacturers are too keen on finding out how a process will not work.

With regard to the mixture of china clay and grog, I think better results would have been obtained by using the silicate of soda without any carbonate. My experiments have all indicated the unsuitability of sodium carbonate for slips made from kaolin.

Concerning the actual experiments, the mould shown by Fig. 1

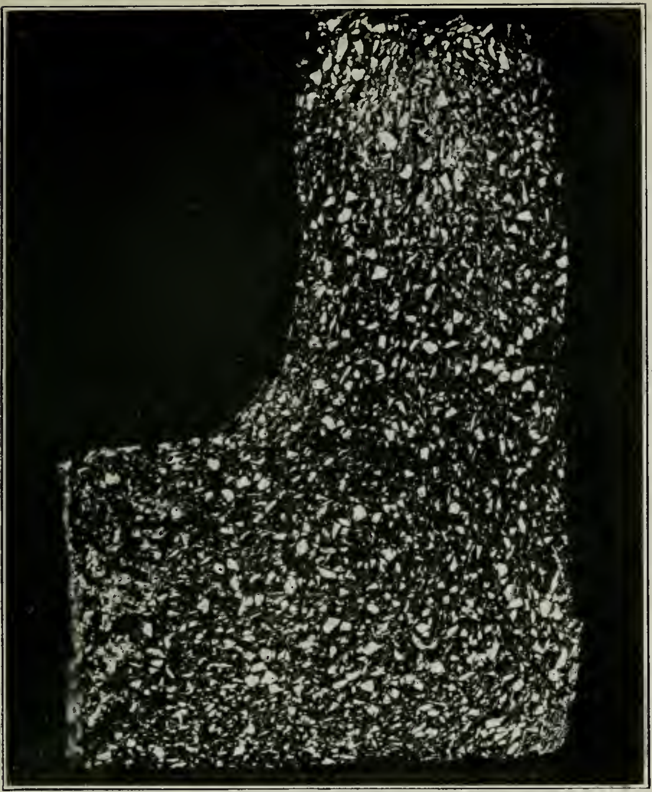

PLATE 9.

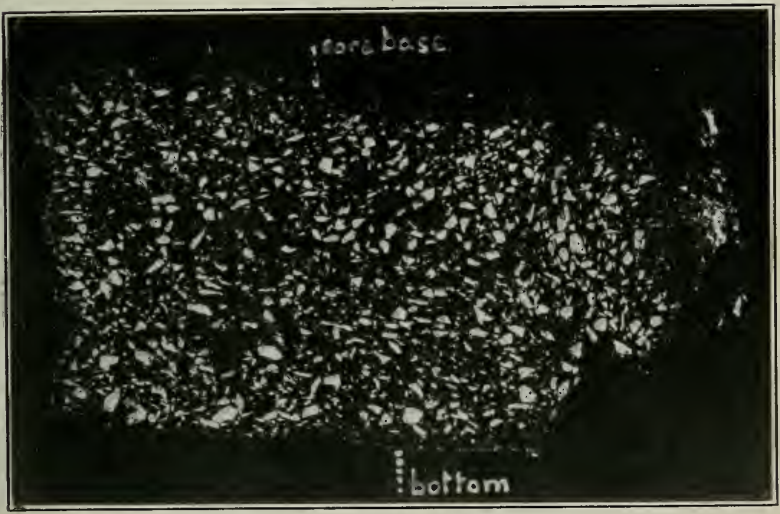

PLATE 10.

[*To face Trans., p.* 150.

would give much better results if filled from the bottom, the funnel being at the side and an air escape hole at the opposite side, this latter to be closed with a plug of clay and a weight when the slip had flown through.

No. 2 experiment would also have given better results if carried out on similar lines. The ring-shaped cracks and fine clay belt are characteristic of casting made with the feed in the position shown on the diagram.

The application of an electric current to assist the deposition of clay is very interesting, and particulars of the methods adopted in applying the current and insulating the mould would be most useful.

From experiments made in this direction, I find that the best voltage for depositing china clay is between 48 and 60, but the current consumption in the experiments I carried out was very much higher than indicated by Miss Taylor.

The most satisfactory results I have obtained were got by using a hollow core, exhausting this core, and using only 0·025 per cent. of alkalies, the water-attracting pole being connected to the core. I am not at all sure that electrical deposition of clay is a commercial proposition for the manufacturer of glass pots, but it is interesting to know that clay slabs are being produced in Germany by electrolytic pressure, which are so dense and hard when they come from the mould that washing with boiling water has no appreciable effect, and the surface can scarcely be scratched by the finger nail.

The apparatus for putting pressure on the slip appears somewhat complicated, and similar results can be obtained by much simpler methods. It would be interesting to know what extra amount of slip was taken by the mould under pressure as compared with the mould filled in the ordinary way. When experimenting in this direction, I have burst several heavy moulds by putting pressure on the slip, but never yet got anything approaching the same density which can be obtained by exhausting the air from around the mould.

As an example, a cored mould taking 2 cwt. of fireclay slip mixture to fill under atmospheric pressure took 2¼ cwt. when filled under a vacuum of 8½ inches on the gauge, and when filled under a vacuum of 26 inches on the gauge 2 cwt. 45 lb. were required to fill the same mould. The barometer in both cases stood at 29·5 inches. A pressure of 10 lb. to the square inch on the slip when the mould was under a vacuum of 26 inches on the gauge increased the slip to 2 cwt. 56 lb. Any figures comparable with these would be most useful, and would enable us to come to some conclusion as to the difference between casting with the mould under reduced pressure and putting pressure on the slip itself.

With regard to the radiographs showing air bubbles, I should be inclined to think that these existed in the slip before being introduced into the mould, rather than they had been entrapped at the base.

With regard to Plate 4, the decomposition of the electrolyte was probably due to the fact that too high a voltage was used, and very much more electrolyte than is necessary for the purpose. China clay is the most satisfactory clay material obtainable for electro-deposition, and should give very little trouble if the correct amount of electrolyte is employed and the right voltage used.

I should like to know why the pressure was reduced from 25 lb. per square inch to 10 lb. per square inch, and suggest that it would be better to reverse the procedure and start with the pressure of 10 lb. per inch and finish with 25 lb. per square inch, the higher pressure being necessary to force the slip into the fissures which arise after the initial deposition of the clay on the mould.

In conclusion, I hope that experiments of the nature covered by Miss Taylor's paper will be extended, and data published which will enable manufacturers and users of pots to come to definite conclusions as to the suitability of various processes for producing pots for particular purposes.

Mr. C. J. Peddle, D.Sc. (*communicated*).—The study of refractories, particularly from the laboratory point of view, has been enriched by Miss Taylor's important contribution, and it is to be hoped that the work will be continued on the much larger scale necessary for making works pots. Results obtained on a large scale would be invaluable in the industry, particularly those obtained from the method of examination of the distribution of clay and grog in the pot. If sections could be obtained from large pots made by Miss Taylor's method and from pots built by a reputable pot-maker, a comparison would show which method was likely to give the pot with the most evenly distributed grog. Miss Taylor's statement that small slip-cast pots are more uniform in structure than built-up pots is borne out by my own experience of pots slip cast on a large scale. Unfortunately, one's experience of large slip-cast pots is very small, for the hand-built pot still holds the day. The time seems ripe for a thorough investigation of the relative merits of the slip-cast pot and the hand-built pot, and the methods worked out by Miss Taylor are eminently suitable for such an investigation. It is evident from the work of Miss Taylor that slip casting under pressure, when properly controlled, has many advantages, and it would be of interest to compare large pots cast in this way with those made by the vacuum casting process worked out by Mr. B. J. Allen.*

An interesting point in the paper was the formation of a clay belt at the bottom of a pot cast under the slight pressure of a head of slip, resulting in the cracking of the pot when fired. In glass practice, it is sometimes found that ordinary hand-built pots develop ring-shaped bottom fracture when a melt has been in progress a short time. Miss Taylor's discovery would suggest that an uneven distribution of grog is a possible cause of this fracture. Investigation on a large scale would again be valuable in this case, as another cause which may be suggested for "ring" bottom fracture, as also for "starfish" bottom fracture, in hand-built pots is the fact that the bottom may be too dry or too wet before the sides are built on, resulting in strain being set up during the drying and subsequent firing.

The photographs illustrating the paper are of particular interest, and one looks forward to the day when similar ones may be available dealing with large pots made by various methods from various refractory mixtures.

XIV.—*The Density of Soda–Magnesia Glasses.*

By S. ENGLISH, M.Sc., and W. E. S. TURNER, D.Sc.

IN a previous paper † containing the results of measurements of the density of the soda lime glasses, we referred to the conditions which must be fulfilled if precise results were to be obtained, and special reference was made to the necessity of thorough annealing.

Fig. 1 illustrates the effect of strain on the density of glass. The three curves are for the various trisilicate soda–magnesia glasses the composition and some properties of which have already been described.‡ Curve 1 is the density curve for crushed glass derived from a rod which had been air-cooled only and not subsequently annealed; Curve 2 is for crushed glass obtained from a slab which had been annealed in the piece without entirely eliminating the strain. Since, also, when not complete, the degree of annealing is likely to vary when, as actually the case, the slabs were not all annealed together, it is scarcely to be expected that the results would all lie on a smooth curve. The deviation is marked by the broken line.

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* This JOURNAL, Trans., p. 78.

† This JOURNAL, Trans., p. 126.

‡ This JOURNAL, Trans., 1919, 3, 275, 278.

These results indicated the necessity for more thorough annealing. When this was done, the densities of glass from both rod and slab coincided, their values being plotted along Curve 3.

The variation of density according to the condition of strain is of considerable interest, inasmuch as parallel results are exhibited by metals. With one or two exceptions, namely, bismuth and antimony, subjecting a metal to hammering, to drawing into wire through a draw plate or to torsion; or, in general, bringing about mechanical deformation, results, not in an increase, but in a decrease in the density. When the metal is re-annealed, the density once more rises, like that of glass, and tends to a constant value.

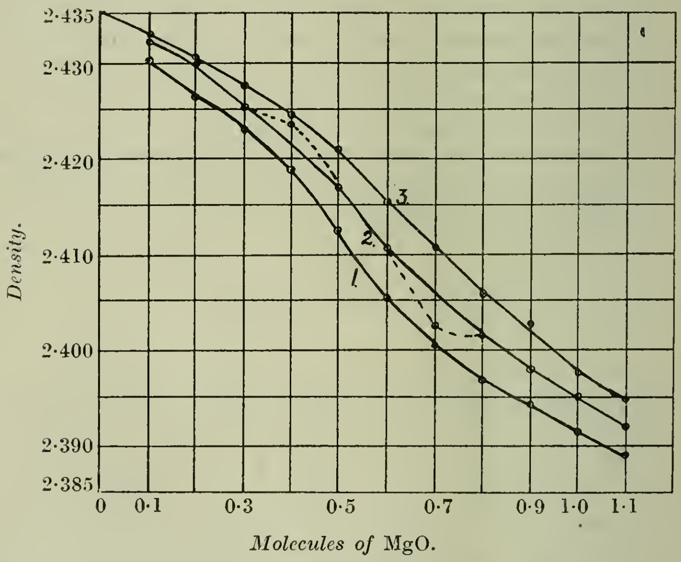


Fig. 1.

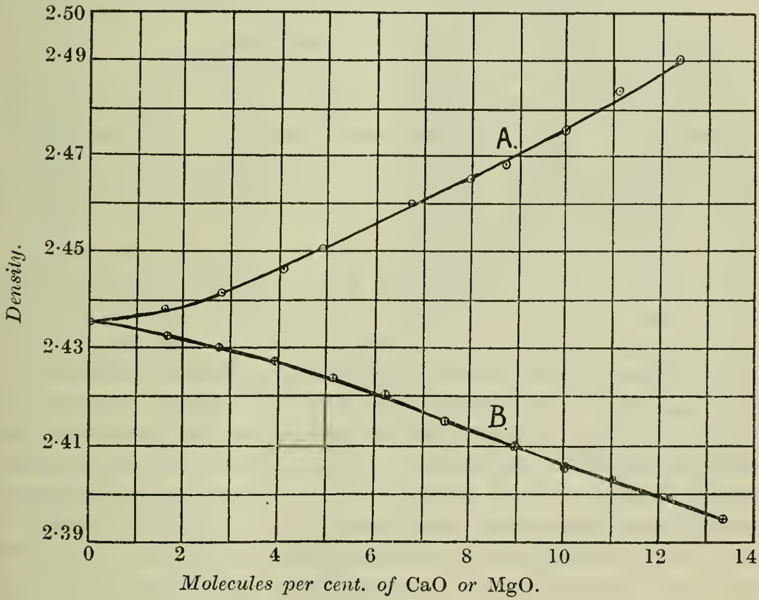
It is because of this effect of strain on the density that the glasses were reduced to small particles of mesh 10 to 30, as in the case of the soda-lime glasses. The general method of procedure was also as described in the previous paper, glasses 24—27 being immersed in toluene and the remainder in water, since they are only very slowly affected by this liquid at the temperature of experiment.

The results are given in Table I:—

TABLE I.

Glass No.	MgO per cent.	Density at 20°.
1	0·0	2·4353
24	1·10	2·4323
25	1·85	2·4300
26	2·49	2·4273
27	3·47	2·4239
28	4·20	2·4207
329	5·09	2·4149
330	6·10	2·4102
331	6·87	2·4055
332	7·46	2·4032
389	8·45	2·3967
390	9·30	2·3947

From the preceding figures it is obvious that as the proportion of magnesia increases and of soda decreases in the glass, the density diminishes, whereas increasing the lime content brought about an increase in density. Hence magnesia differs in its effect from lime.



A. *Soda-lime.*
B. *Soda-magnesia.*

FIG. 2.

Fig. 2 sets out the results for both lime and magnesia-containing glasses, the densities in each case being plotted against molecular percentage composition, and not percentage by weight. In both cases the graph exhibits curvature at the end, but is for the remainder of its course a straight line. The conclusion to be drawn, then, in both cases, is that the relationship between density and composition is linear,* the deviation which occurs being at the end of the series.

The Calculation of the Density.

We have already pointed out † that in the case of the lime-soda glasses, Winkelmann and Schott's factors do not lead to close agreement between the observed and the calculated densities. Much greater is this divergence in the case of the magnesia glasses. For, since Winkelmann and Schott's factor for Na_2O is 2·6 and for MgO 3·8, it would obviously follow that increasing density would result by continuous displacement of soda by magnesia, resembling the lime glasses. Precisely the opposite takes place.

That Schott's factor for MgO was not correct was recognised by Tillotson, who deduced new values, namely, for CaO 4·1 and for MgO 4·0. As we indicate below, these factors do not lead to good agreement for our glasses. There appeared to us too little difference between the factors for CaO and MgO to correspond to the diverging density curves.

For this reason we have attempted to deduce new factors. In order to do this, some assumption has to be made in regard to the density factor of SiO_2. We may assume, as we did in the case of the thermal expansion data, that silica, in combination with silicates, has the same density as in the pure fused state, and in this case the value would be 2·206, the density deducted by Chappuis. There is not much justification for the assumption, for usually chemical combination is accompanied by contraction, although in one or two metallic alloys even expansion is known. Winkelmann decided on the density value 2·3 as best fitting his own results, this figure, if correct, indicating contraction on combination. Peddle,‡ by extrapolation from the results of the density of various sodium silicates, arrived at the value of 2·20 ~~2·40~~ for silica. Here, again, because of extrapolation there cannot be certainty.

In Table II we set out three sets of calculated results—(1), (2), and (3). Under (1) and (2) are values calculated by new factors derived by us, the first, assuming that the density factor for silica is 2·20; in the second case by assuming, with Winkelmann, that the factor is more correctly 2·3. Using these two values and proceeding in a similar manner to that described in a previous paper,* the following factors were deduced:—

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* Compare Larsen, *Amer. J. Sci.*, 1909, **28**, 263.

† This Vol., Trans., p. 126.

‡ This Vol., Trans., p. 3.

	(1)	(2)
SiO_2	2·20	2·30
Na_2O	3·47	2·9
MgO	3·38	2·9

It will be noted in the first place that the value for Na_2O does not correspond to that deduced by Winkelmann (namely, 2·6).

Tillotson's factor for MgO was 4·0, and he assumed SiO_2 as 2·3 and Na_2O as 2·6. These were used in obtaining the results in column 1.

TABLE II.

Calculated Values of Soda-Magnesia Glasses.

	Composition.				Calc. Density.		
Glass No.	SiO_2.	Na_2O.	MgO.	Obs. Density.	(1)	(2)	(3)
24	74·07	24·23	1·10	2·4323	2·440	2·443	2·394
25	74·35	23·46	1·85	2·4300	2·433	2·436	2·394
26	75·00	22·12	2·49	2·4273	2·427	2·433	2·397
27	75·16	20·69	3·47	2·4239	2·431	2·438	2·412
28	75·19	19·83	4·20	2·4207	2·431	2·439	2·418
329	76·30	18·26	5·09	2·4149	2·413	2·425	2·418
330	77·09	16·05	6·10	2·4102	2·412	2·429	2·429
331	76·68	15·77	6·87	2·4055	2·414	2·430	2·428
332	76·86	14·55	7·46	2·4032	2·419	2·438	2·447
389	77·77	13·40	8·46	2·3967	2·397	2·419	2·441
390	78·28	11·76	9·30	2·3947	2·397	2·427	2·446

Of the three sets of calculated results, it is clear that those obtained by the use of the factors under (1) give closest agreement with the observed results, whilst those under (3) (Tillotson) are most discordant. It is only fair to point out, on the other hand, that our factors, (1) and (3), do not fit Larsen's data so well as do Tillotson's. From other data we are accumulating, however, we hope to be able to check all the factors discussed.

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* English and Turner, this Vol., Trans., p. 115.

XV.—*The Discoloration produced by Lead, Antimony, and Arsenic in Lampworked Glass Tubing.*

By F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

During the course of a long series of glass meltings for the production of tubing for lampworking purposes, we found, as recorded in a previous paper,* that the addition of white arsenic or of antimony oxide to the batch always led to a glass which became discoloured on working in the blowpipe flame. The facts then ascertained seemed to us to be worthy of closer study; for, as we pointed out at the time, whilst most of the best samples of lampworking tubing previously made on the Continent were free from arsenic or antimony, occasionally arsenic was present, whilst in one noteworthy case as much as 3·45 per cent. of antimony oxide was contained in the finished glass.

Arsenious oxide and antimony oxide are not the only oxides liable to cause discoloration in lampworked glass. Lead oxide, for example, may be a source of trouble. When the glass is known to be a lead glass, it can be worked satisfactorily in the oxidising part of the flame. The blackening of tubing, not ostensibly of lead glass, has been alleged to be due to the accidental addition of lead glass cullet to the batch, but the amount of such cullet necessary to produce the effect has never been ascertained, nor has the amount of lead oxide.

It seemed desirable, therefore, to obtain final proof of the detrimental effects of arsenious and antimony oxides, to ascertain what amounts were effective in causing discoloration, and to determine what proportion of lead oxide was necessary to cause blackening. Some experiments were also made on the influence of manganese dioxide. The arsenious oxide employed in the melts was of high quality and free from any trace of material which might cause blackening. The antimony oxide was highly purified. The original sample contained 99·56 per cent. actually of antimony oxide and 0·22 per cent. of lead oxide. Whilst it was fully proved later that such a minute proportion of lead oxide was wholly without influence, we nevertheless purified the antimony oxide until even the small amount of lead oxide as stated was removed.

As a standard glass, our No. 373, which we found excellent for lampworking purposes, was selected. The batch from which it was produced was as follows:—

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* This Journal, Trans., 1919, **3**, 266.

	Parts by weight.
Sand	1,000
Felspar	367
Limespar	220
Soda-ash (95 per cent.)	448
Potash (90 per cent.)	151
Magnesia (90 per cent.)	4

As it was obvious that much of the glass tubing produced would be useless for working because of discoloration, it seemed wasteful to make the meltings on the same large scale as previously, namely, in 56-lb. crucibles, and, accordingly, small crucibles holding ½—1 lb. only were employed, and samples taken out on a very small pipe and drawn into tubing. The crucibles were covered with a lid during the melting operation. The glass tubing produced was subsequently subjected to excessive working, both in the oxidising and in the reducing flame, in order to bring about any discoloration, if such were obtainable.

The Effect of Lead.

Amounts of red lead were added to batch No. 373 so as to produce definite percentages of lead oxide in the actual finished glass. These percentages present (approximately) in the series of melts made (series 451*a*—*k*) were as follows:—

Series 451.

a	0·01	*f*	0·20
b	0·02	*g*	0·30
c	0·05	*h*	0·40
d	0·10	*j*	0·50
e	0·15	*k*	0·60

When tested, none of the samples *a* to *j* showed discoloration, but with sample *k* containing 0·6 per cent. PbO it was readily obtained, the actual colour shown being grey to black.

It is the rule in melting lead glasses to add nitre to the batch in order to prevent reduction with consequent blackening due to the possible effect of the fuel gas. There was no indication that reduction had occurred during the melting of any of the glasses of series 451, but, as a precaution, another series of ten meltings, No. 452, was undertaken, corresponding in every way with series 451 *a*—*j*, with the exception that one-sixth of the soda-ash in the batch was replaced by its equivalent of soda nitre.

The results of the tests with the new series were precisely identical with those for the series without nitre. There was clear evidence, therefore, that 0·5—0·6 per cent. of lead oxide (PbO) must be present in a glass before it suffers discoloration when worked in the blowpipe flame.

The Effect of Arsenic.

In these tests arsenious oxide was added so as to produce in the finished glass the following percentages:—

Series 453.

a	0·01
b	0·02
c	0·05

Two sets of meltings were made with these different quantities. In the first set discolouring effects were found with all three glasses, that is to say, even where the glass contained only one part in ten thousand of arsenious oxide. The colouring was a faint bluish-grey, almost silvery in appearance. In the second set no effect was noticed until the third member of the series, namely, the one containing 0·05 per cent., the colour here being brown.

A further series of melts, with percentages of arsenious oxide as follows, was carried out, the batch containing soda nitre in the same proportion as series 452.

Series 454.

a	0·01	*d*	0·1
b	0·02	*e*	0·15
c	0·05	*f*	0·2

The tests made on the tubing drawn from these glasses gave similar results to the second set in series 453, namely, that discoloration was obtained only when 0·05 per cent. had been reached and the colour obtained was brown. Hence one may say definitely that the presence of between 0·02 and 0·05 per cent. of arsenious oxide in a glass for lampworking purposes will lead to discoloration of the finished articles. This fact is of importance, and emphasises our previous view that arsenic should not be used in a batch for producing lampworking tubing.

The Effect of Antimony Oxide.

Antimony oxide was added so as to yield glasses with certain percentages, as below:—

Series 455.

a	0·01	*d*	0·1
b	0·02	*e*	0·15
c	0·05	*f*	0·2

A further series, No. 456, of six glasses was made, differing only from the above in that soda nitre was present.

In both cases the results were identical with those obtained with arsenic, namely, that up to a content of 0.02 per cent. there was no discoloration, whilst the glass with 0.05 per cent. and upwards was discoloured when worked. Further, as with arsenic, the colour was brown.

The Effect of Manganese.

We have previously made a considerable number of tubing melts with batches containing manganese dioxide without any indication of discolouring effects.

In order to carry further this study of the possible effect of manganese, we prepared a further series of glasses containing manganese dioxide sufficient to serve as a decoloriser (0·2 part per 100 of sand), where lead oxide, arsenious oxide, or antimony oxide was already present in just sufficient quantity to cause discoloration. In other words, glasses with and without nitre in the batch, namely, 451*k* and 452*k* (lead glasses), 453*c* and 454*c* (arsenic glasses), and 455*c* and 456*c* (antimony glasses) were prepared containing manganese.

Discoloration was obtained with the tubing drawn from each sample. The addition of manganese dioxide, therefore, did not suppress the tendency to discoloration. Indeed, by comparison of the various discolorations obtained, the effect of the manganese dioxide was, if anything, to increase it slightly.

Summary and Conclusions.

Fifty small-scale meltings of a good lampworking glass were made with the addition of graduated quantities of lead oxide, arsenious oxide, antimony oxide, with and without nitre, and with and without manganese dioxide decoloriser.

The results showed that both arsenious and antimony oxide are very potent in causing discoloration when the glass is worked in a flame, far more so than lead oxide.

The minimum amount of arsenious and antimony oxides required to be present in the glass to yield discoloration lies between 0·02 and 0·05 per cent.; or between 2 and 5 parts in 10,000.

For lead oxide very much more, namely, 0·6 per cent., is required.

The results appear to be independent of the presence of nitre in the batch, whilst the presence of manganese dioxide, in amount sufficient to act as a decoloriser, does not hinder the appearance of discoloration.

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XVI.—*The Composition, Drying and Firing Shrinkage, Porosity, and Density of British Fireclays* suitable for Glass Furnace Refractory Materials.*

By Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc., and
W. E. S. Turner, D.Sc.

(*Read at the Sheffield Meeting, April 21st,* 1920.)

The results contained in this memoir have been obtained during the course of the last eighteen months. It was hoped that they would have been available several months ago, but difficulties arising from the war and its aftermath have been met at every stage, particularly in regard to the supply of necessary apparatus or parts of apparatus used in the preparation of the clays, and of furnaces used in firing them—so much so that even now the data presented are not so complete as we could desire before publication. In particular, two or three clays remain to be examined completely, as also the tests at 1500°. It is thought, however, that the results so far achieved may be of immediate service both to glass and to glass refractories manufacturers, and for this reason it is not necessary for them to remain unpublished for a further three months.

The work undertaken had its origin in the labours of the Refractories Research Committee of the Society, and it is through the financial assistance of that Committee, and of the late Optical Munitions Branch of the Ministry of Munitions, that its commencement was made possible. The authors desire at the outset to acknowledge the debt they owe to the Refractories Research Committee for its generous support.

Early in 1919, the Refractories Research Committee was able, after several months of discussion, to complete a Provisional Specification † for Glass Works Refractory Materials, the sections specified being tank blocks, silica bricks and blocks, and clay for pots. The specifications were based on the best available experience and practice, and whilst they embodied as far as possible the glass manufacturer's desires, the requirements were tempered by what glass refractories manufacturers could reasonably be expected to produce. Obviously, the elaboration of such a series of specifications emphasised the existence of many gaps in our knowledge of refractory materials. In the first place, it was quite within the bounds of possibility that there were many clays, hitherto either but little or entirely unused for glass refractory materials, which might be of no less value than those already well known. Moreover, the commonly used fireclays do not appear ever to have had their properties systematically examined, or, if so, the results have not been published. Then, again, since an attempt was made in the Provisional Specification to classify fireclays suitable for glass refractories into three grades, according to their chemical composition, limits being also set to the composition of bind and base clays in each grade, it was evidently desirable either to reinforce the specifications by experimental evidence or to provide material for their modification. For these reasons, it appeared wise to start at the beginning, to gather fireclays from as many British sources as possible, and systematically to examine all their properties which are of importance when considering them as of possible service in the manufacture of refractory materials.

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* In order to avoid misunderstanding, the authors desire to point out that the clays investigated are entirely samples of raw clay as mined, and not the mixtures of clays which the refractories manufacturer employs for the purpose of the preparation of refractory materials.

† Recently (April), one of us was informed by a representative of a very large dealer in glass refractory materials that, despite the fact that the specification had now been published for more than a year, his firm had not received a single application from any glass manufacturer for goods to be supplied to that specification. On enquiry, another glass refractories manufacturer stated that he had no recollection of being requested to supply to specification. In this case the manufacturer said he himself would not be prepared to adopt a series of specifications of the

The general plan of work which we have set ourselves to carry through includes the investigation of the chemical composition of the clays, together with the shrinkage on drying and firing, the porosity, density, and refractoriness both with and without load. The raw clays having been examined, it is proposed to attempt their purification and to determine its effect on the properties mentioned. The study of the effect on the shrinkage and porosity when various clays are mixed will follow, as also the influence of the relative proportions and the sizes of grog particles.

Further, it is hoped to be able to carry out experiments on the corrosive influence of the raw materials and of glass batches on burnt prepared fireclays.

Such investigations will go far to provide information of great practical importance to makers of glass pots and blocks and to glass manufacturers themselves; but they will by no means complete the data required for a more scientific study and understand-

character drawn up. A great deal of work was done by the Refractories Committee when the specifications were drawn up, and both glass manufacturers and refractories manufacturers concurred in the findings of the Committee. It would be of untold advantage to both industries if all refractories goods ordered were specified as fulfilling the conditions laid down by the specifications issued.

ing of furnace operations. Thus, we require much fuller information about the thermal expansion of refractory materials. Some valuable data of this kind have already been obtained, as, for example, those recently derived by Hodsman and Cobb.* What is now required is a systematic study of the thermal expansion at temperatures between 1000° and 1500° or 1600°. The losses of heat from furnaces, as the result of conduction through the refractory materials used in their construction, call for close study, whilst the mechanical strength, that is, both the tensile and compression strength, of the various fireclays, after being fired, all require to be tested. Until substantial progress has been made with such studies, scientific workers will still be left to conjecture when attempting to build up a scientific account of furnace practice.

The Tests Employed and their Objects.

In the present paper, a record is given of the chemical compositions, the drying and the firing shrinkages, porosity, apparent and actual densities of twenty-seven British fireclays, at a series of temperatures up to 1400°, as well as certain miscellaneous information gathered while the tests were in progress.

Ordinary clay is not a simple substance, but a mixture of minerals of very varying compositions. Its study, therefore, does not lend itself to the precise methods of chemistry. All that can be done is to draw up a series of empirical tests which are likely to make comparison easy and to be capable of precise repetition on different samples of clays. Standard methods of testing refractory materials have already been the subject of inquiry by the English † and the American Ceramic Societies. Subject to the modifications mentioned in the text, we have adopted in these investigations the standard methods of the former.

Chemical Composition.

The chemical composition of a clay is always one of the tests made. In this paper the object was twofold. In the first place, it was desired to determine whether the clay was or was not suitable for a glass refractory, on account of the proportion it contained of harmful oxides, such as iron oxide, or because there was too great a proportion of fluxes; and in the second place, it was desired to check the classification by chemical composition, which was adopted provisionally in the specifications issued by the Refractories Committee.

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* This JOURNAL, Trans., 1919, **3**, 201

† *Trans. Cer. Soc.*, 1918, **17**, 300.

The determination of drying and firing shrinkage gives information valuable to the actual worker with clays. For example, in practice, in pot-making, it is always essential that the thinner parts shall not be allowed to dry at a distinctly greater rate than the thicker. It is clear, also, that a clay which undergoes a big shrinkage when drying is one that can only be used with a considerable amount of risk. One well-known method of reducing shrinkage is to add grog; but obviously the shrinkage can be brought under control very much better if it has been actually determined from stage to stage of the firing range, and particularly if a clay with a small uniformly changing shrinkage be used.

The knowledge of the firing shrinkage should prove useful when the refractory material leaves the drying-room and is passed forward for its preliminary heating. In the case of a clay pot, very great care has to be exercised when it is fired in the pot arch. A series of changes occurs in the clay, accompanied by very considerable shrinkage. During heating, water is gradually driven off during the firing stage to about 600°, whilst the burning out of carbonaceous matter takes place mainly between that temperature and 900°. Physical changes in the minerals composing the clay also lead to volume changes. The firing, that is to say, the rate at which the temperature is raised, should therefore be modified according to the degree of shrinkage which takes place from stage to stage. Here, again, a clay with a small regular shrinkage may prove to be better than one with a big shrinkage taking place irregularly. In any case, however, if the actual shrinkage from stage to stage is known, the refractory material which is being heated can more safely be treated.

The porosity of a clay produces notable effects on its properties, particularly in regard to resistance to chemical corrosion and thermal conductivity. The more porous the clay material, the better does it serve as a thermal insulator, at any rate at those temperatures exhibited by the outer parts of furnaces. In regard to corrosion, however, the more porous a fireclay block or pot, the more rapidly will molten glass bring about corrosion, owing to the largely increased surface exposed as compared with the non-porous surface. Resistance to corrosion can therefore be achieved by any or all methods which lead to the production of a dense, non-porous body.

The density, both actual and apparent, of clay fired at different temperatures does not perhaps lead to such valuable information as the properties already mentioned. By studying the density, however, it is possible to determine at what stage the clay becomes overfired, and, therefore, useless for furnace use; for at a certain point a clay begins to become vitreous, and following this it may undergo some decomposition, leading to a sponginess being developed through the evolution of gas. In this stage it obviously begins to lose strength and to be useless in the furnace. In such a condition it is spoken of as being overfired.

The Clays Tested.

The clays examined are given in Table I, where they are also numbered, these numbers being employed in all subsequent tables for the sake of brevity.

TABLE I.

No. of clay.	Source.	No. of clay.	Source.
1	Mansfield.	15	Halifax.
2	Kilwinning.	16	,,
3	Coalbrookdale.	17	Ruabon.
4	Ayrshire bauxitic clay.	18	Armadale.
5	Kilmarnock.	19	Stourbridge *A* (Netherend).
6	Wortley.	20	,, *B*
7	Kilwinning (aluminous shale)	21	,, *C*
8	Huddersfield.	22	,, *D*
9	Huddersfield.	23	,, *E*
10	Grossalmerode.	24	,, *F*
11	Halifax.	25	,, *G*
12	,,	26	,, *H*
13	,,	27	,, *I*
14	,,		

We are very much indebted to Messrs. Edinburgh and Leith Flint Glass Co. for clays Nos. 1—5; the Leeds Fireclay Co. for Nos. 6—9; Messrs. Parkinson and Spencer for Nos. 11—16; to Messrs. Evers and Sons for Nos. 20—22; to Messrs. Wood Bros. Glass Co., Ltd. for No. 10; Messrs. J. C. Edwards for No. 17; Messrs. United Collieries, Ltd. for No. 18; Messrs. King Bros. Ltd. for Nos. 19, 23, and 24; Messrs. Trotter, Haines and Corbett for No. 25; and Messrs. Mobberley and Perry for Nos. 26 and 27.

The clays were all received in 5-cwt. samples as representative of bulk supplies. Some of them were already crushed and ground. A number, however, were supplied in lump form, and it was necessary to grind them. This was done in a small Sturtevant roll grinder.

We found that the grinding of the clays produced particles of different sizes, according to the mode and extent of grinding, and the various commercial samples had particles differing considerably in size. There were two methods of procedure possible, either to attempt to reduce all the clays so that the particles were of the same size, or to use the commercial material after determining the various grades of particles present. As in practice the manufacturer would not attempt to grade the clay particles, we did not reduce the clay particles to a common size, but accepted them as received, ground, or as ground by ourselves. We hope later to test how far the size of the particles of raw clay affects the properties of the articles made from it.

The ground clay was first passed through a 30-mesh sieve to remove coarse particles. The material passing through was then graded into three portions, namely: (1) a portion not passing through a 60-mesh sieve, (2) a portion passing between 60- and 90-mesh, and (3) a portion passing the 90-mesh. Each portion was weighed, and the results for the various clays were as follows:—

TABLE II.

Percentage of differently-sized Particles in the Clays used.

No. of clay.	(1) 30—60-mesh.	(2) 60—90-mesh.	(3) Smaller than 90-mesh.
1	45	20	35
2	45	20	35
3	45	20	35
4	5	5	90
5	35	10	55
6	35	15	50
7	40	20	40
8	60	20	20
9	55	20	25
10	50	15	35
11	25	70	5
12	30	65	5
13	30	60	10
14	35	55	10
15	50	15	35
16	50	15	35
17	55	20	25
18	50	45	5
19	50	35	15
20	60	35	5
21	60	20	20
22	55	25	20
23	50	30	20
24	45	35	20
25	50	40	10
26	55	20	25
27	45	20	35

After removal of the coarse particles, namely, those which failed to pass through a 30-mesh sieve, the clay, with its mixture of sizes of particles as above, was dried at a temperature of 65°, then mixed thoroughly with water, and allowed to stand at least overnight, sometimes for two days. The excess moisture was removed by wedging the mixture on a plaster slab until the clay was brought to a suitable working consistency. After this had been attained, slabs were made from the clay in brass moulds of dimensions $4\frac{1}{2}$ inches × $1\frac{1}{8}$ inches × 9/16 inch.

It appeared desirable to determine the amount of water which was required in order to reduce the clay to a state suitable for working. With this object, two portions of the prepared clay in each batch, after the proper working consistency had been arrived at, were weighed on a watch-glass and dried at 110° until of constant weight. It was found that the amount of water required was approximately constant for each batch. Table III states the amounts of water required for the various clays expressed as a percentage of the dry clay.

TABLE III.

Percentage of Water required to produce Working Consistency.

No. 1	26·1	No. 10	26·4	No. 19	21·2
2	26·3	11	23·4	20	21·0
3	23·1	12	25·1	21	22·7
4	26·1	13	21·7	22	18·1
5	23·0	14	27·6	23	22·4
6	22·4	15	29·0	24	25·4
7	22·4	16	26·6	25	21·2
8	22·0	17	23·5	26	23·8
9	28·5	18	21·6	27	20·4

There does not appear to be any relation between the amount of water required and the composition of the clay, nor does there appear to be any relationship between the size of particle and the amount of water required, as will be seen on comparing Table III with Table II.

The Chemical Composition of the Clays.

Table IV contains the composition of the clays examined. The specification published by the Refractories Research Committee states the compositions only in terms of the fired or ignited material. In order to economise space, therefore, we quote only the compositions of the clays after ignition. As a check on the clay, however, we have quoted the loss which was experienced on ignition, and the sum total of the constituent oxides obtained by the analysis of the raw clays.

It will be seen that the clays vary very considerably in chemical composition. Thus we have several of high alumina content, such as Nos. 1, 2, 3, 7, and 22, and notably No. 4, where the alumina content exceeds that of the silica. On the other hand, nine of the clays contain more than 70 per cent. of silica, their alumina content being correspondingly low.

As already stated, one of the objects of determining the chemical composition was to be able to check the classification suggested by the provisional specification.

The Calculated Mineral Composition of the Clays.

From time to time attempts have been made to differentiate between the various constituents which go to make up the body of a clay. Thus the "rational" analysis aims at determining the

TABLE IV.

Calculated Composition of the Clays after Ignition.

No. of clay.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	K_2O.	Na_2O.	Composition of the raw clay.	
									Total oxides.	Loss on ignition.
1	52·12	41·11	2·81	1·37	0·53	Trace.	0·98	1·07	86·67	13·27
2	51·82	41·15	2·56	1·42	nil	0·30	1·89	0·86	87·89	12·28
3	53·79	38·86	2·80	1·64	0·47	0·28	2·07	0·07	85·83	14·43
4	42·36	52·48	1·16	3·31	trace	trace	0·34	0·35	85·93	14·13
5	64·13	29·73	2·60	1·57	trace	trace	1·20	0·77	90·60	9·68
6	64·34	29·47	2·67	1·33	0·27	0·51	1·18	0·20	89·98	10·34
7	49·34	39·13	5·62	4·33	0·27	0·42	0·71	0·17	86·62	13·79
8	73·40	21·14	2·60	1·17	0·17	0·53	0·61	0·39	93·22	6·94
9	71·90	22·54	2·59	1·17	0·17	0·49	0·72	0·42	93·26	7·26
10	75·26	19·09	1·70	2·00	0·44	0·36	0·77	0·17	93·91	6·24
11	74·71	19·27	3·65	1·22	trace	0·24	0·61	0·29	93·18	7·18
12	75·60	19·26	2·30	1·27	0·13	0·40	0·89	0·16	93·06	7·35
13	68·03	25·37	3·04	1·12	0·24	0·70	1·12	0·38	91·15	9·36
14	63·65	29·49	3·40	1·12	0·24	0·66	1·21	0·31	90·90	9·49
15	74·35	19·02	3·56	1·17	0·25	0·54	1·00	0·12	93·25	6·97
16	74·91	19·90	2·57	1·03	0·21	0·34	0·80	0·24	93·52	6·67
17	54·25	37·15	2·88	1·48	0·42	0·99	2·83	trace	89·11	10·77
18	55·64	35·55	4·67	1·81	0·20	0·44	1·24	0·45	88·90	11·52
19	68·58	25·21	2·52	1·75	0·33	0·28	0·96	0·37	91·68	8·31
20	71·93	23·41	1·96	1·06	0·51	0·28	0·74	0·11	92·34	8·10
21	60·46	31·67	2·83	1·32	0·40	0·92	2·19	0·20	89·98	10·08
22	57·35	37·27	2·19	1·20	0·48	0·45	0·42	0·67	86·90	13·48
23	68·82	27·04	1·60	1·39	0·22	0·33	0·60	trace	91·00	9·20
24	66·64	28·02	1·83	1·41	0·38	0·55	1·13	0·04	90·94	9·45
25	56·52	36·61	2·71	1·54	0·32	0·54	1·67	0·09	85·36	14·95
26	69·61	25·39	1·75	1·44	0·18	0·44	1·18	trace	91·74	8·57
27	73·58	21·70	1·39	1·43	0·34	0·29	0·85	0·41	93·04	7·51

mineral composition by removing each constituent in turn with a suitable chemical reagent. The process has long been recognised, however, as unsatisfactory.

Recently, another method of setting out the mineral composition of clays was suggested by Washington.*

We have followed this method, and in Table V (p. 171) are the results. The calculation, following Washington, is made on the assumption that all the potassium present exists as *orthoclase* ($K_2O,Al_2O_3,6SiO_2$), the sodium as *albite* ($Na_2O,Al_2O_3,6SiO_2$), the calcium as *anorthite* ($CaO,Al_2O_3,2SiO_2$), the iron as *limonite* (Fe_2O_3,H_2O), magnesium as *serpentine* ($3MgO,2SiO_2,2H_2O$), titanium as *rutile* (TiO_2), the remaining aluminium as *kaolinite* ($Al_2O_3,2SiO_2,2H_2O$), and silica, if any then remaining, as quartz. Where the alumina is in excess of the silica, the silica is calculated to *kaolinite*, and the alumina remaining as Al_2O_3.

The results of the calculations would appear to indicate that the clays are mainly distinguished according as they are made up of a high proportion of *kaolinite* or as they contain a great deal of free silica or a certain amount of free alumina. In the case of one clay, namely, No. 17, the results of the chemical analysis cannot be dealt with so successfully as with the other clays, for it will be seen that we have to introduce a negative quantity for the water and organic matter.

The results present several interesting features, which it is possible may be of value as the study of the clays proceeds. At the moment, however, their value, for the purpose of this paper, is to be measured by the degree of success with which the results can be linked up with the values of the properties of the clays measured. It must be confessed that the results are disappointing. This is so if we consider the results of the shrinkage tests; for example, clays Nos. 10 and 12 are not very dissimilar in their main mineral content, since they have apparently nearly the same amount of free silica and of *kaolinite*. Whilst the shrinkages, however, are somewhat similar up to a temperature of 900°, beyond that No. 10 has a rapidly increasing shrinkage, whereas No. 12 alters but little. A similar conclusion is arrived at by comparing No. 10 with No. 15.

There are three possible deductions to be drawn. One must admit, in the first place, that the differences in the minor constituents exercise a noteworthy influence on the shrinkage, or that a knowledge of the mineral composition does not assist very much, certainly in the present instances; or, again, that Washington's method of mineral analysis is itself faulty. The fact remains that

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* H. S. Washington, *J. Amer. Cer. Soc.*, 1918, **1**, 4.

TABLE V.

No. of clay.	Orthoclase.	Albite.	Anorthite.	Kaolinite.	Limonite.	Serpentine.	Quartz.	Rutile.	Water and organic matter.	Free alumina.
1	5·00	7·86	2·56	76·42	2·70	trace	—	1·19	2·33	2·12
2	9·84	6·39	nil	74·20	2·49	0·61	—	1·25	1·59	3·78
3	10·51	0·52	1·97	77·40	2·68	0·55	1·92	1·40	3·30	—
4	1·72	2·52	trace	72·26	1·12	trace	—	2·85	4·16	15·71
5	6·40	5·97	trace	62·13	2·67	trace	20·95	1·41	0·75	—
6	6·23	1·52	0·80	62·72	2·67	1·05	22·85	1·10	1·20	—
7	3·78	1·26	1·14	82·30	5·41	0·83	0·41	3·75	1·66	—
8	3·34	2·67	0·78	45·79	2·68	1·10	42·30	1·09	0·31	—
9	4·00	3·25	0·78	48·99	2·68	1·05	38·65	1·09	0·02	—
10	4·23	3·04	2·03	40·02	1·78	0·77	46·03	1·88	0·38	—
11	3·34	2·31	trace	42·72	3·77	0·50	45·81	1·14	0·77	—
12	4·89	1·26	0·58	41·90	2·38	0·85	46·21	1·18	1·02	—
13	6·00	2·67	1·08	53·35	3·08	1·46	30·39	1·00	1·34	—
14	6·56	2·36	1·08	62·59	3·36	1·38	21·82	1·00	0·24	—
15	5·50	0·94	1·14	40·76	3·68	1·16	45·13	1·09	0·77	—
16	4·45	1·94	0·99	43·27	2·67	0·74	44·96	0·97	0·27	—
17	14·90	trace	1·83	75·13	2·86	2·01	2·01	1·32	—(0·26)	—
18	6·50	3·30	0·89	74·46	4·61	0·88	7·58	1·61	0·55	—
19	5·23	2·88	1·47	53·30	2·35	0·60	31·88	1·61	0·56	—
20	4·00	0·84	1·78	50·75	1·99	0·61	38·72	1·00	0·72	—
21	11·68	1·52	1·78	64·29	2·83	1·90	14·33	1·19	0·75	—
22	2·21	4·92	2·08	76·54	2·26	0·89	8·19	1·04	2·45	—
23	3·28	trace	1·03	59·75	1·62	0·69	31·96	1·26	0·61	—
24	6·06	0·37	1·72	59·86	1·85	1·16	27·34	1·28	0·76	—
25	8·45	0·68	1·33	73·53	2·56	1·05	7·08	4·21	1·32	—
26	6·39	trace	0·83	55·13	1·78	0·91	33·28	1·32	0·58	—
27	4·67	2·67	1·58	46·10	1·50	0·61	41·22	0·85	1·33	—

no real help is forthcoming by an attempt to correlate mineral composition, as here determined, and physical properties.

Classification of the Clays by the Provisional Specification.

In the Provisional Specification, the chemical compositions of clays for tank blocks and for pots were stated somewhat differently. In both cases, bind clay and base clay were specified separately.

For tank blocks, the bind clay, after being fired, should, it was suggested, contain 36 to 40 per cent. of alumina, less than 2·5 of total alkalies, and less than 4·5 of total fluxes, whilst free silica should exist in small proportions only.

The base clay, it was suggested, should contain 25 to 32 per cent. of alumina, less than 1·4 per cent. of total alkalies, and less than 4·0 per cent. of total fluxes.

In the case of raw clay for pots, the summarised specifications for the three grades were:—

	Bind clays.			Base clays.		
	I.	II.	III.	I.	II.	III.
SiO_2	$<60·0$	$<65·0$	$<70·0$	$<55·0$	$<60·0$	$<70·0$
Al_2O_3	$>34·0$	$>30·0$	$>25·0$	$>40·0$	$>35·0$	$>25·0$
Fe_2O_3............	$<1·8$	$<2·5$	$<2·5$	$<1·0$	$<2·0$	$<2·0$
Na_2O and K_2O	$<1·8$	$<2·0$	$<2·5$	$<1·5$	$<1·8$	$<1·8$
MgO and CaO	$<1·0$	$<1·0$	$<1·0$	$<0·5$	$<0·6$	$<1·0$

When the actual clays are brought up for judgment according to the standards set out above, one is forced to the conclusion that if the standards are to be maintained intact, the bulk of the British clays so far studied stand condemned unless they can be purified. Consider, for example, the iron oxide content. For a bind clay for pot-making, the limit for Grade I is 1·8 per cent. Only five clays, namely, Nos. 4, 10, 23, 26, and 27, could pass muster, although No. 24 is just on the limit only. But, as stated below, No. 4 is useless as a bind clay, and as a base clay its Fe_2O_3 content is greater than is allowable for Grade I.

Only in one other clay, namely, No. 20 (Stourbridge *B*), does the Fe_2O_3 fall below 2 per cent. Of the others, no fewer than seventeen have more than 2·5 per cent. of ferric oxide, the limit even for Grade III.

Consider now the clays which, having sufficiently low iron oxide content, fall within one or other of the Grades I—III. No. 4 (Ayrshire bauxitic clay) nearly reaches Grade I standard. It contains, however, 3·31 per cent. of titanium oxide, the influence of which is not fully known and has been neglected in the provisional specifications. Further, No. 20 has slightly too little alumina and correspondingly too much silica to meet even the standard of Grade III. In the non-British clay No. 10 (Grossalmerode), the Fe_2O_3 permits it to be considered as a possible Grade I bind clay, and so also do its alkaline and alkaline-earth constituents, but the alumina and the silica content place it outside the scope even of Grade III. No. 7 would from the point of view of chemical composition only meet the specifications for tank-block requirements, but its iron oxide content is obviously much too high, being 5·62 per cent., which absolutely excludes it.

Applying the standards of the provisional specifications, we should be forced to the conclusion that of the 27 clays, there were, judged by the chemical composition, only five British clays which came within the Grades I—III, namely, Nos. 4, 19, 23, 24, and 26, the first not quite reaching Grade I standard for a base clay, the second only just meeting the requirements for a bind clay of Grade III, and Nos. 23, 24, and 26 fulfilling quite readily the conditions for Grade III, bind or base clay.

Clearly the outlook for British clays, unless subjected to considerable purification, would be narrow if they were judged by the analytical composition stated in the provisional specification. Although it is certain that most, if not all, the clays would benefit by purification, it is equally certain that to attempt to draw up limits of composition which various classes of clays must strictly fulfil is premature. The simplest plan, in the opinion of the authors, would be to stipulate that the iron oxide content shall not exceed a certain value, and then to judge the clay further by its physical properties, such as the shrinkage and porosity, determined at various temperatures, as well as by its working properties. The chemical composition alone is likely to give quite misleading information. We do indeed find that similarity of chemical composition is usually accompanied by similarity in working properties. This is clearly seen in the description of the individual clays. On the other hand, clays of similar composition may have very different shrinkages and porosities, so that it does not appear possible to correlate chemical composition and physical properties with any real satisfaction.

From our own experience of their working properties, we can state which of the clays examined might be used as bind- and those which may be suitable as base-clays. Coalbrookdale, Ayrshire, Kilwinning Aluminous Shale, Stourbridge *C*, *D*, and *G* (Nos. 3, 4, 7, 21, 22, and 25 respectively) could only, so far as our experience leads us, be employed as base clays. The others all have binding power to a greater or smaller degree, whilst in certain circumstances, in combination with some other clay, they might be employed as base clays.

Very approximately, the binding power of the clays, judged by the working properties, is in the order stated in Table VI, the first in the list having considerable binding power, the last four being practically devoid of it.

TABLE VI.

Approximate Order of Binding Power.

Clay No.	Clay No.	Clay No.	Clay No.
15 and 16	27	18	25
11 and 12	23	19	4
8	6	1	—
9	5	17	7
24 and 26	10	2	3
13 and 14	20	21	22

THE SHRINKAGE, POROSITIES, AND GENERAL CHARACTERISTICS OF THE INDIVIDUAL CLAYS.

In this section it is proposed to describe briefly the important characteristics of each clay examined.

The shrinkage on drying or firing was determined by drawing two parallel lines 9 cm. apart across the width of the clay slab before drying, and, after firing, measuring the contraction of the distance between the lines. Subsequent to the air drying, the slabs were heated at 110° until of constant length, and similarly at 200°, 350°, 500°, etc., up to 1400°. The firing was carried out in a series of specially-built electric tube furnaces with nichrome wire wound on silica for temperatures up to 1000°, and platinum or platinum–rhodium on alundum tubes from 1000° to 1400°. The diminution in length was expressed as the percentage of the length when wet.

Special attention is directed to our method of firing, since the procedure is a departure from the standard methods of the Ceramic Society. In these standard methods the slab is heated up together with a cone designed to reach the required temperature, and as soon as that temperature is attained the slab is removed. Our method was to fire several slabs for several hours at the temperature required, and, after determination of the shrinkage, to fire them a second and third time, if necessary, until the shrinkage was constant; indeed, some were fired four times, each period consisting of several hours. The necessity for repeated firing was greatest at the highest temperatures.

The porosity determinations were possible only at temperatures of 600° and more. The fired slabs were weighed in air, covered with water in a vacuum desiccator, and air was exhausted until no further bubbles could be extracted from the slabs. Subsequent to this treatment, the slabs remained soaking in water for two days *in vacuo*. After being weighed suspended in water, the surface moisture was wiped away and the slabs weighed again. If x was the weight in air, y that when suspended (after soaking) in water, and z the weight in air of the soaked slab, the percentage porosity is $100\,\frac{(z-x)}{x-y}$.

For the ready comprehension of the shrinkage and porosity data, they are given in graphical form in this section, the broken line showing the variation of the porosity with the temperature, and the unbroken line the shrinkages.

(1) *Mansfield Clay.*—This clay has a high alumina content. The proportion of iron oxide and rather high total alkalis mar what would otherwise be an excellent clay, but weathering and careful sorting would almost certainly lead to much improvement. When worked up with water, it was fairly smooth to the touch and quite plastic. It does not appear to possess much binding power. On being burnt, it becomes pink at 600°, very pale at 1100°, cream-coloured at 1200°, and grey at 1400°.

The shrinkage (Fig. 1) is but moderate, and increases only slightly and comparatively uniformly to 750°, from which point there is rapid increase. At 1400° the shrinkage has reached a high value, exceeding 15 per cent., the greatest shrinkage found for any clay examined. Rapid firing above 750° would have to be avoided, although the rate of shrinkage is moderately uniform.

The porosity increases to a maximum of 30·9 per cent. at 900°, and then falls rapidly and fairly uniformly to 8 per cent. at 1400°. The maximum porosity is higher than in most other clays, and only three other clays have a lower minimum. It presents, therefore, a wide range of porosity change.

(2) *Kilwinning.*—In chemical composition this is very similar to No. 1, except that it contains distinctly more total alkalis. In working properties and colour changes observed it was also very similar to No. 1, although the colour after 1300° was rather darker.

The shrinkages and porosities (Fig. 2) follow a very closely similar course to those of the Mansfield clay, except that the rapid increase of shrinkage is postponed until 900°, whilst the porosity at 1400°, although small, is not so low.

(3) *Coalbrookdale.*—This has approximately 2·5 per cent. less alumina than Nos. 1 and 2, and correspondingly more silica, other-

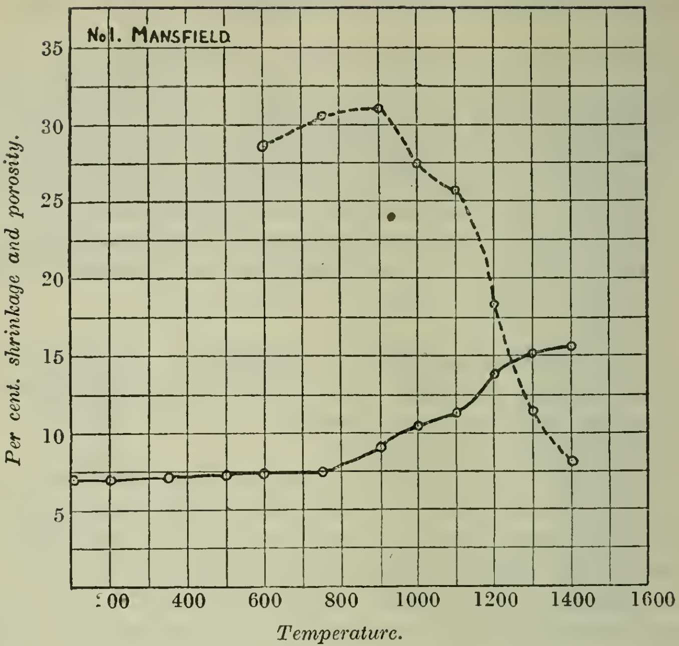
No 1. MANSFIELD
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 1.

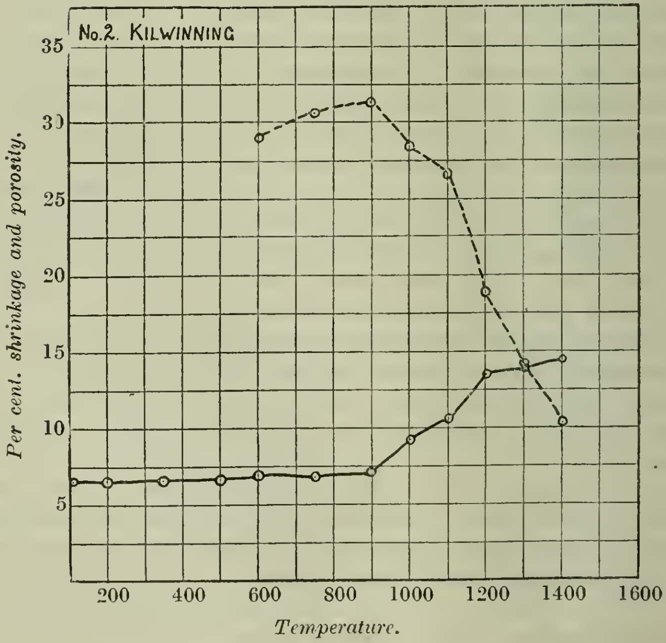
No. 2. KILWINNING
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 2.

wise it is not very dissimilar. It is rather rough to the touch, very short in working, and not easy to keep as a coherent mass. On being heated the clay is grey at 600°, yellowish-pink at 750°, pink at 900°, becoming paler at 1100° and yellow at 1200°. This last colour deepens at 1400°.

The shrinkage (Fig. 3) is rather small, rises only slowly and uniformly to 900°, but after that fairly rapidly and somewhat irregularly to 1400°, the maximum shrinkage being found at 1200°, not 1400°. Careful heating would therefore be desirable between 1100° and 1300°.

The high maximum porosity is reached, not at 900°, but at 750°, and then decreases rapidly, but without the change of direction such as is shown by the shrinkage.

(4) *Ayrshire Bauxitic Clay.*—This clay is remarkable in several ways. It has a very high alumina content, containing 10 per cent. more alumina than silica, and, according to the mineral composition (p. 171), nearly 16 per cent. must be in the free state. Its titanium oxide content is high, but it is freer from iron oxide than all the other clays examined. When prepared it is very smooth and greasy, rather short in working, and dries badly, difficulty being observed in drying the slabs owing to the development of cracks. At 600° the colour is pale cream, at 750° very pale pink, and at 1300° and 1400° a pale cream.

The shrinkage (Fig. 4) is very small initially, but begins to increase noticeably at 400—500°. There are sharp contractions between 900—1000° and 1100—1300°, followed in each case by an interval, in which the shrinkage remains stationary.

The porosities are in marked contrast to those of most other clays. The maximum, between 750—900°, is very high, the change in porosity quite smooth, and at 1400° still quite high, namely, 25·8 per cent. Unless there is a marked change at 1500°, it would not be possible to incorporate much of the clay in flux-line tank blocks, owing to its high porosity.

(5) *Kilmarnock.*—This clay, which has a moderate alumina content, is fairly smooth to the touch and quite plastic when prepared with water. It is almost entirely free from the alkaline earths. When heated it assumes a pale pink tint at 600°, which does not vary appreciably up to 1200°. At this stage it becomes cream-coloured, darkening at 1300—1400°.

The shrinkage (Fig. 5) is quite small, and the slight steady increase is only broken at 1000°, when the shrinkage takes place more rapidly. Nevertheless, it is still uniform from stage to stage between 1000° and 1400°.

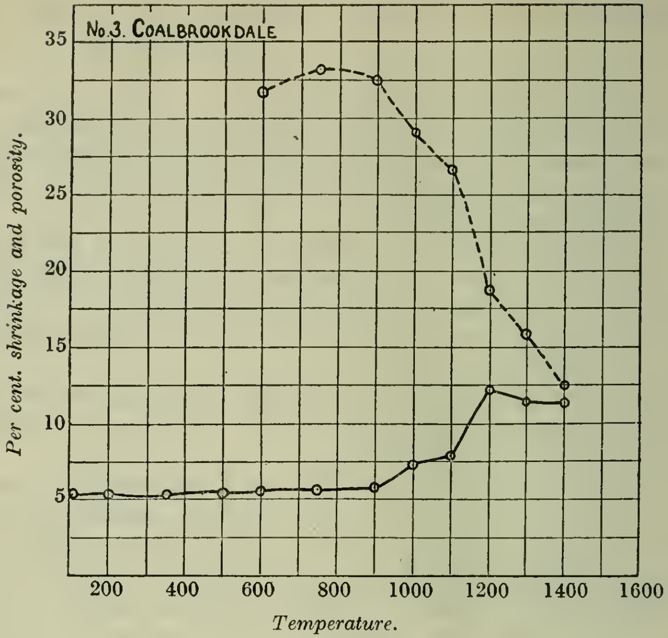
No. 3. COALBROOKDALE
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Per cent. shrinkage and porosity.
Temperature.

FIG. 3.

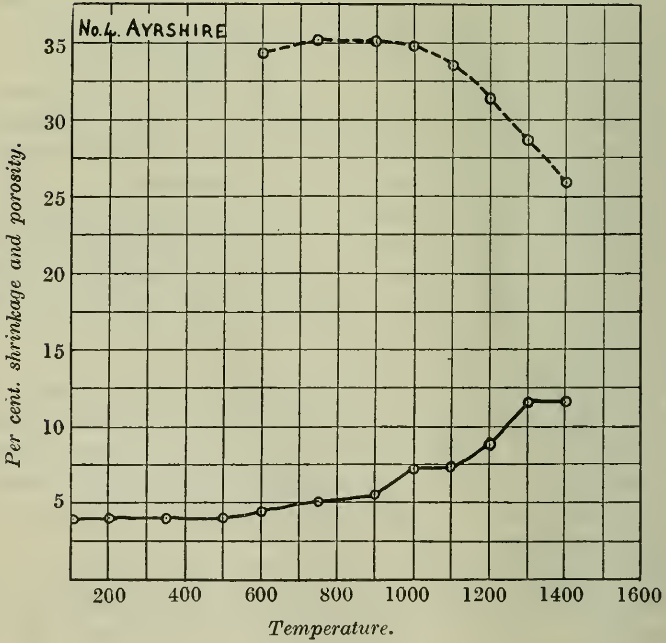
No. 4. AYRSHIRE
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Per cent. shrinkage and porosity.
Temperature.

FIG 4.

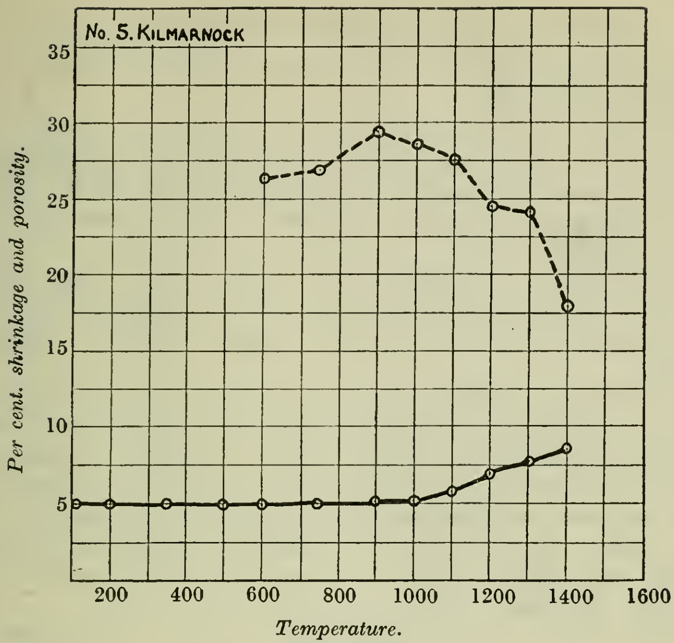
No. 5. KILMARNOCK
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 5.

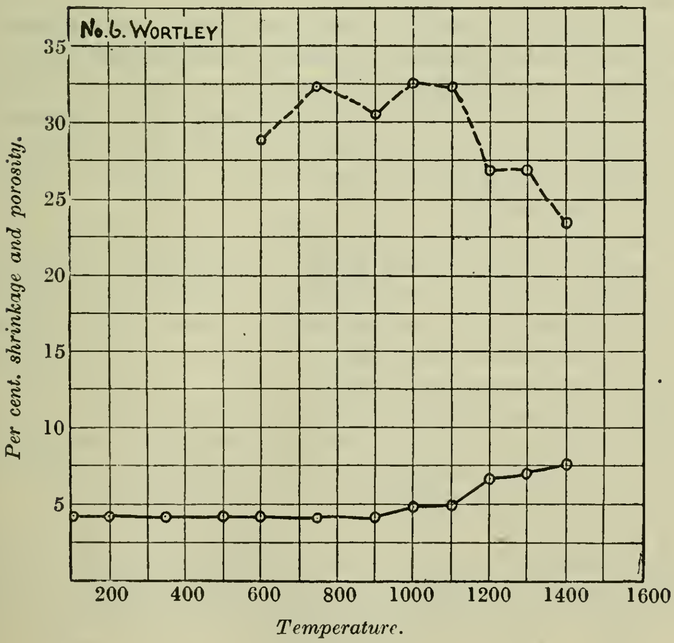
No. 6. WORTLEY
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 6.

The porosity does not present any very noteworthy features, and the range is not wide.

(6) *Wortley.*—Except that lime and magnesia are present, this clay bears a distinct similarity to Kilmarnock in composition. Like that clay, it is smooth to the touch and fairly plastic, and its colour changes on heating are almost identical, though rather greyer at 600°.

The changes in the shrinkage and porosity (Fig. 6) are not so regular as in the case of Kilmarnock clay. Indeed, the porosity–temperature curve contains two maxima, whilst the range is limited.

(7) *Aluminous Shale, Kilwinning.*—This material has a high alumina content (39 per cent.). The iron oxide content is very high, and so also is the titanium oxide. Although in respect of alumina and silica composition the material is similar to clay No. 2 from the same neighbourhood, in other respects the materials are very unlike. To the touch it is rough and sandy and not very plastic, and slabs of it have a tendency to develop cracks when drying in the mould.

When burnt, a brown, speckled colour, due to the iron content, is obtained at 1400°. The initial shrinkage (Fig. 7) is low, steadily increasing to 1100°, sharply changing between 1100° and 1200°, and then again, but slowly, from 1200—1400°. The porosity is remarkable. It is higher than with any other clay examined, and remains high over the whole range temperature, being only slightly less at 1400° than at 600°. Without considerable treatment, it would by itself not be suitable for any refractory article in which a dense body were desirable, although with a suitable bind clay it might be of much value.

(8) and (9) *Leeds Pot Clays.*—Both these clays are of the siliceous type and very closely similar in composition and working, being quite smooth and very plastic, particularly the No. 2 clay. Both show a tendency to hold air-bubbles. Both develop the same colour on being fired, being slightly pink up to 1200°, becoming yellower as the temperature rises to 1400°.

Both clays have shrinkages (Figs. 8 and 9) which vary continuously and quite slowly. The porosities never reach a high value, and the values at 1400° are nearly identical. The range is greater in the case of No. 9.

(10) *Grossalmerode.*—This is a well-known German clay frequently imported by this country before the war. It is of the highly siliceous type, but very smooth and greasy when prepared with water, and holds air very tenaciously in tiny bubbles. It is quite plastic. Up to 1100° it is very pale pink in colour, cream-

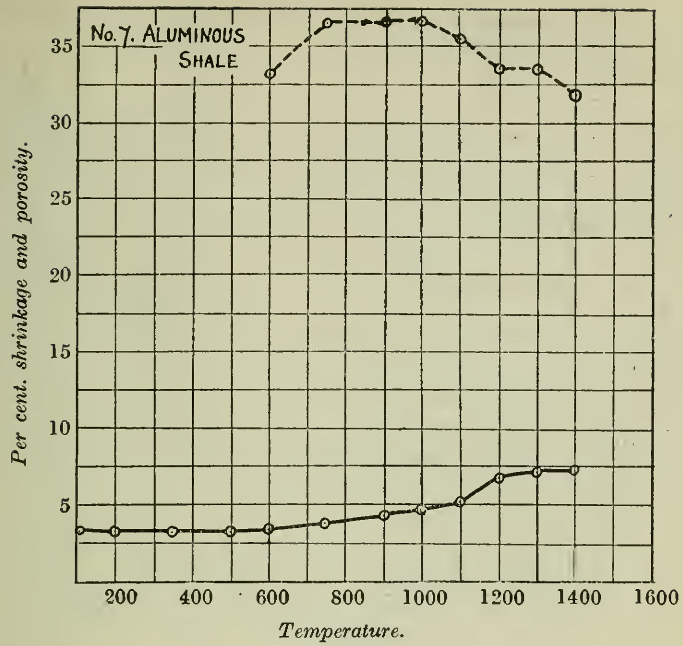
No. 7. ALUMINOUS SHALE
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 7.

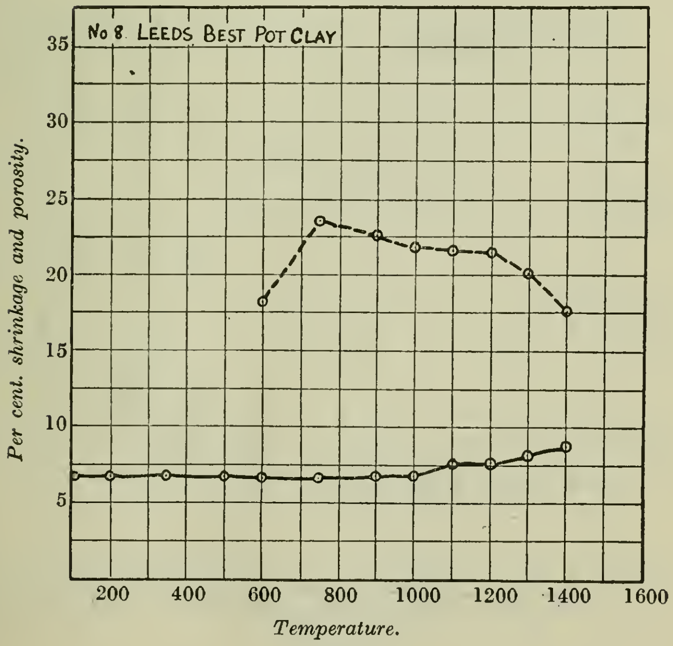
No 8. LEEDS BEST POT CLAY
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 8.

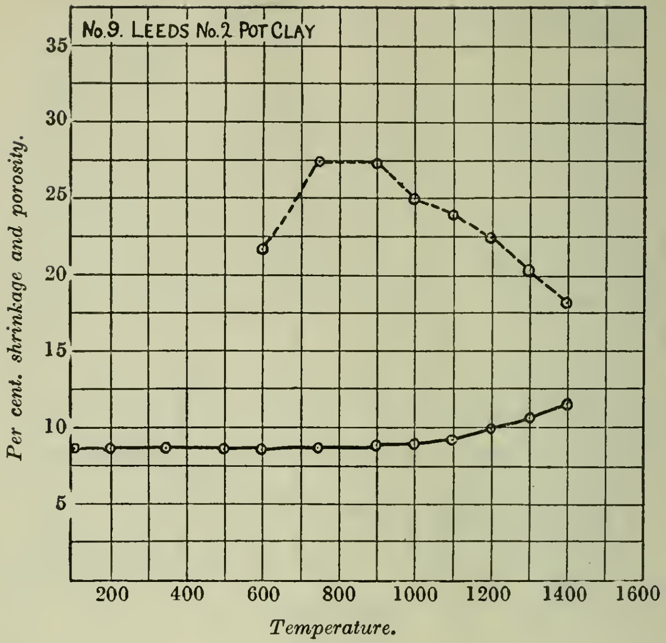
No. 9. LEEDS No. 2 POT CLAY
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 9.

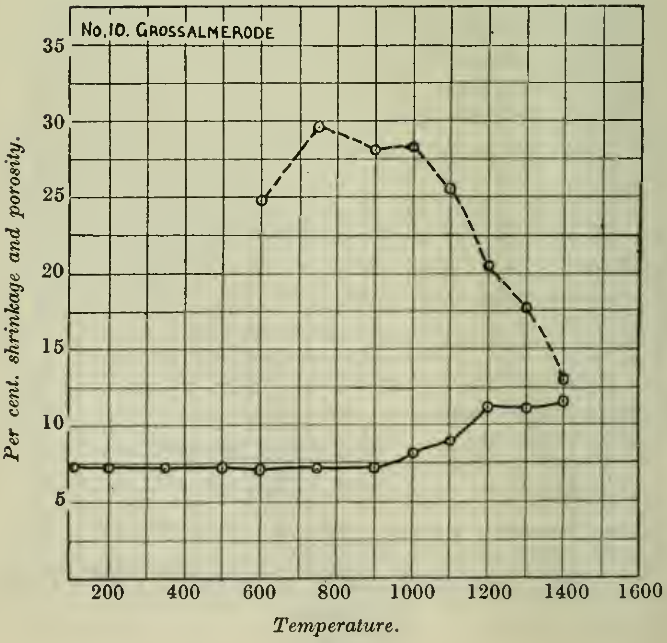
No. 10. GROSSALMERODE
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 10.

coloured at 1200° and 1300°, and yellow, slightly speckled with vitreous matter, at 1400°.

Between 100° and 900° the shrinkage (Fig. 10) remains practically constant, and then rises rather irregularly to 1400°. The first stage of firing (up to 900°) should therefore be comparatively easy with articles made from this clay, with care needed beyond that temperature.

The porosity shows a fairly wide range and reaches an early maximum, namely, at 750°.

(11 and 12) *Halifax Nos.* 1 *and* 2.—These are closely similar and may be dealt with together. Both have a low alumina content, and the main difference in chemical composition is the larger iron oxide content of the former. This larger iron oxide content does not appear noticeably to affect the properties. Both work very smoothly and are greasy, being similar in consistency to Grossalmerode (the chemical composition in the main being similar), but are more plastic. When burnt, the colour changes of clays Nos. 11 and 12 are similar, No. 12 being slightly darker, and at 1400° both exhibit a speckled appearance.

The resemblance between the shrinkages and porosities (Figs. 11 and 12) of the two clays is very close indeed. Both are noteworthy by reason of the small change in shrinkage up to 1400°, by the uniformity with which the change occurs, rendering firing easy, and finally by the very small range of the porosity.

Although in composition and working properties these clays are similar to Grossalmerode, they are superior to it in respect of shrinkage. On the other hand, their porosity does not permit so wide a range of application as the Grossalmerode.

(13) *Halifax No.* 3.—This clay works smoothly, is very plastic, and not so greasy as Nos. 11 and 12. At 1400° the fired clay showed decided speckling.

The figure (Fig. 13) indicates general likeness of shrinkage and porosity results to Nos. 11 and 12, but the change in shrinkage between 900° and 1400° is more marked. The porosity values show a slightly more open range.

(14) *Halifax No.* 4.—There is a general resemblance in composition between this clay and No. 6 (Wortley). Like No. 6, and also like No. 13, it works smoothly and is very plastic. At 1400° it has become grey with some speckling, and shows a tendency to soften.

Whilst the similarity of chemical composition to No. 6 is accompanied by similarity of working properties, there are considerable differences found in the shrinkage and porosity (Fig. 14). The shrinkage of No. 14 is greater than with No. 6, but more regular,

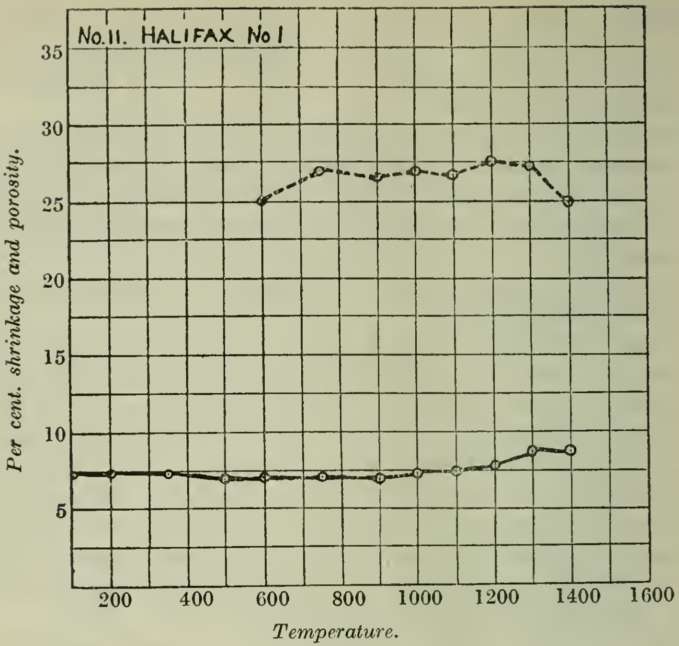
No. 11. HALIFAX No 1
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

Fig. 11.

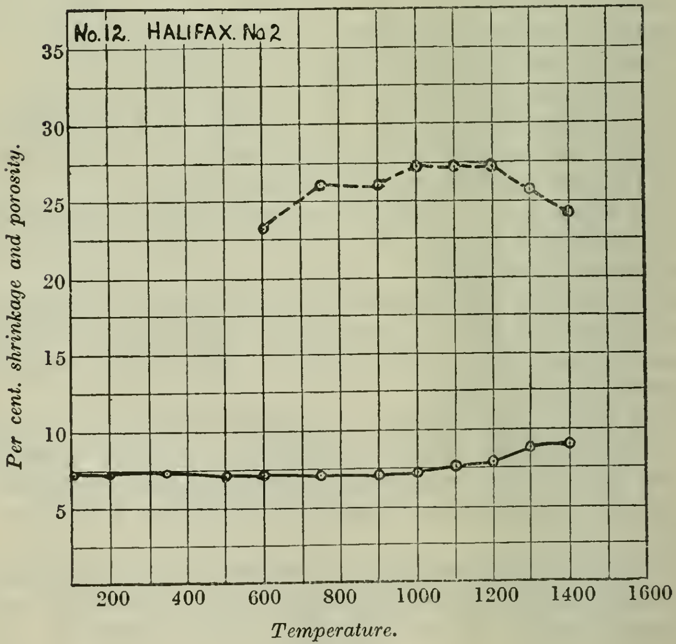
No. 12. HALIFAX No 2
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

Fig. 12.

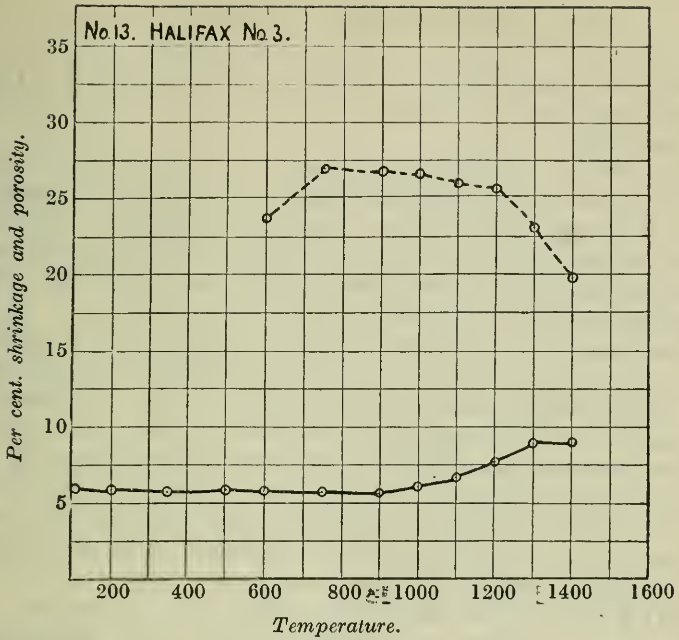
No.13. HALIFAX No.3.
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 13.

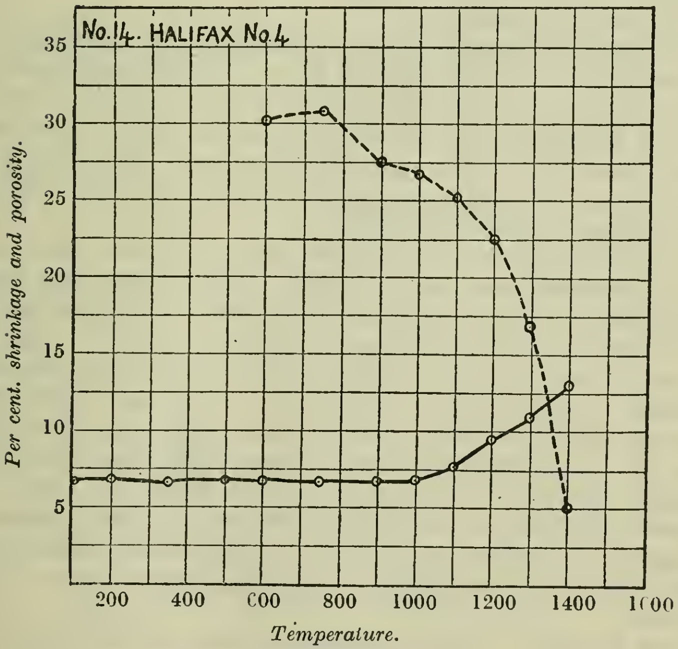
No.14. HALIFAX No.4
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 14.

whilst the porosity shows a very wide range, making it valuable, apart from other considerations, for preparing a wide range of tank furnace blocks.

(15 and 16). *Halifax Nos.* 5 *and* 6.—These clays are highly siliceous, and, save for slightly higher total fluxes in the composition in No. 15, are like Nos. 11 and 12 respectively. This similarity extends to the working properties, but Nos. 15 and 16 retain small air-bubbles more tenaciously than Nos. 11 and 12. Slight speckling at 1400° is also shown by the clays.

The shrinkages and porosities (Figs. 15 and 16) are very similar up to 1300°. Very little change in the shrinkage takes place up to 1000°, and after that a gradual change to 1300°. A rather big increase in the shrinkage occurs between 1300° and 1400°.

The porosities show but little change over the whole range from 600—1300°, but there is a marked drop, especially with No. 15, between 1300° and 1400°. Generally speaking, the porosity range is not great. It is, however, distinctly greater than that found in the somewhat similar clays Nos. 11 and 12.

(17) *Ruabon.*—This has a rather high alumina content. The proportion of alkaline (almost wholly potash) and alkaline earth oxides (or, in general, the proportion of fluxes) is greater than in any other clay examined.

Except for the higher alkali and alkaline earth contents, No. 17 is very similar in composition to No. 3. Rough to the touch, the particles appear to be sharper or more angular than those of No. 3. No. 17 is distinctly more plastic than No. 3, easy to work, but is not a bind clay in the strict sense of the term. The colour change is not great, the clay being grey at 600°, almost white at 1100°, and grey and speckled at 1400°.

The shrinkage (Fig. 17) is steady up to 900°, and then a rapid but uniform increase occurs to 1200°. From 1200—1400° there is practically no change. Similar changes occur in the case of No. 3 up to 1300°, but there is then an expansion to 1400°. Both Nos. 3 and 17 have a great porosity range with almost corresponding changes at the various temperatures. After very little change between 600° and 1000°, there is a decrease in the porosity of No. 17 of more than 15 per cent. between 1000° and 1200°, and a further decrease of 7 per cent. between 1200° and 1400°. The porosity range cannot fail to make this clay valuable, especially if reduction of the iron contents, and possibly some reduction of the alkali, can be accomplished without seriously affecting the porosity range.

(18) *Armadale.*—This is a clay of between moderate and high alumina content. The large amount of iron does not influence the

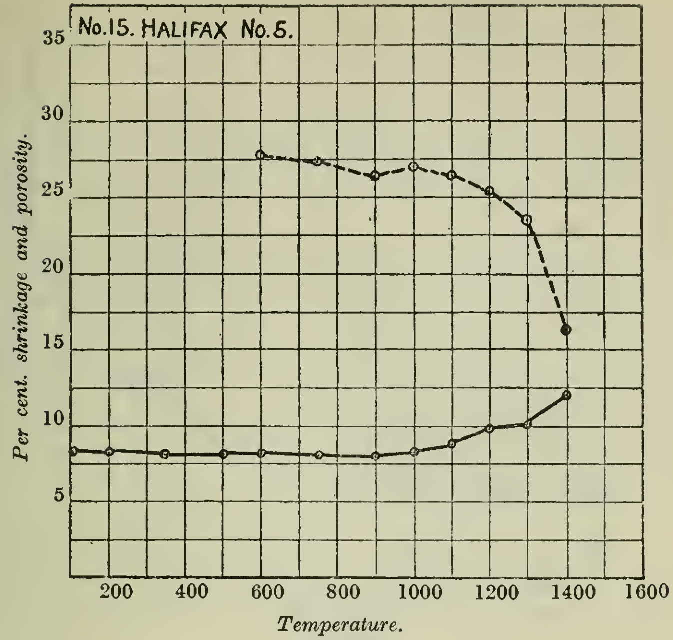
No.15. HALIFAX No.5.
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 15.

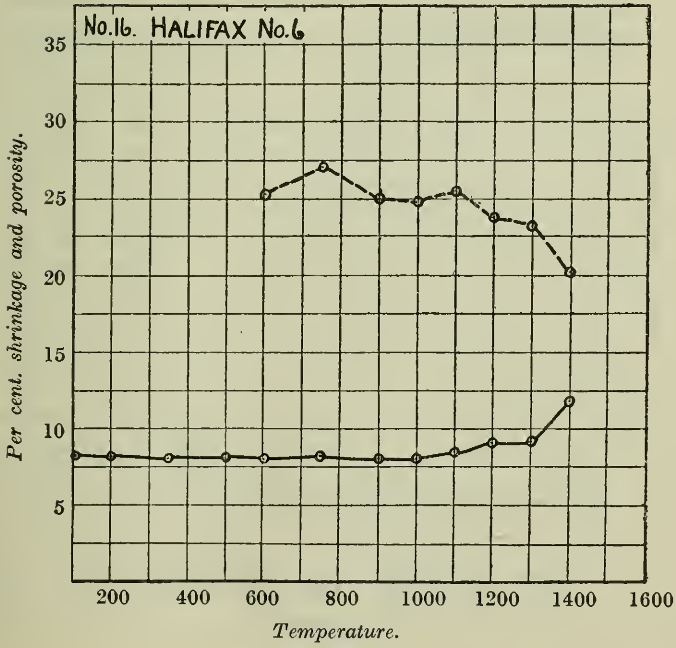
No.16. HALIFAX No.6
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 16.

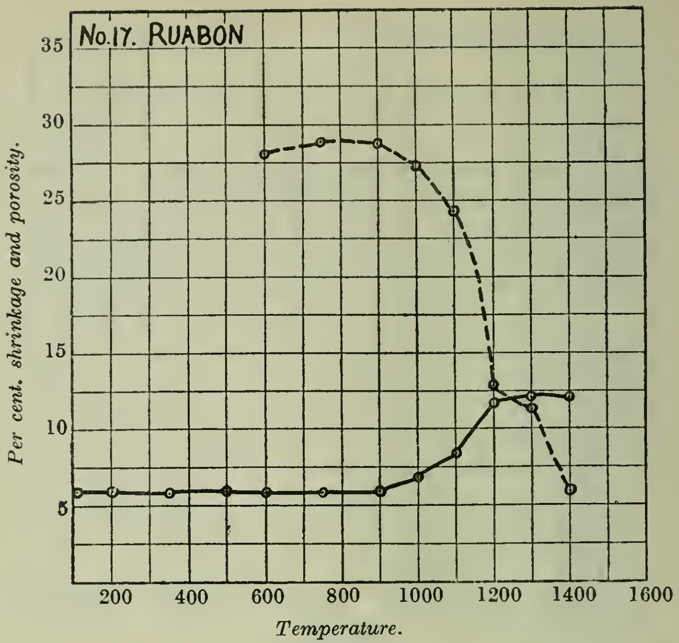
No. 17. RUABON
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 17.

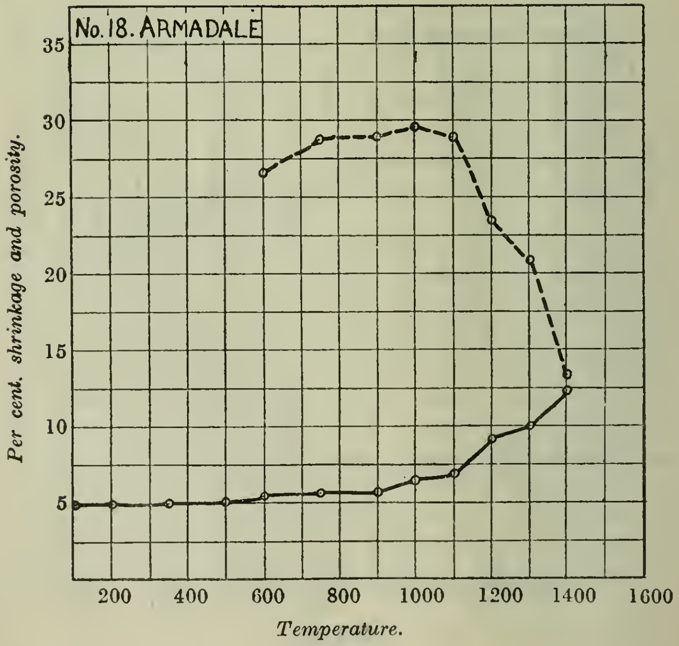
No. 18. ARMADALE
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 18.

colour to the extent that might be expected. At 600° it is pink, but with a purple tint when contrasted with the yellowish tint of Nos. 11—16. It is almost white at 1300°, but darkens to yellowish-brown at 1400°, and is speckled with grey-coloured particles. The clay is smooth, quite plastic, but is inclined to be rather short in working.

A very steady and gradually increasing shrinkage (Fig. 18) occurs up to 900°, then a slightly greater increase takes place between 900° and 1100°, and a fairly rapid one up to 1400°. The porosity change corresponds fairly well with the shrinkage, comparatively little alteration occurring between 600° and 1000°, a slight decrease being apparent at 1100°, and then a rapid decrease to 1400° of more than 10 per cent. Though the changes in shrinkage and porosity in the case of No. 15 are steadier, there is not the difference between those of No. 15 and No. 18 that might be expected from the great difference in composition.

(19) *Stourbridge* A (*Netherend*).—This clay is one which, in its condition as received, comes within the limits of a Grade III clay, according to the provisional specification. When wet it contained spots which appeared blue, and these became reddish-brown on drying, this colour being retained on firing. The main body of the clay was cream at 600°, slightly darkening to buff at 1400°. It was fairly smooth, plastic, quite easy to bring to a good working consistency, and did not hold air-bubbles.

A very small shrinkage (Fig. 19) up to 1400°, mainly occurring between 1000° and 1200°, ensures easy firing, provided reasonable care is taken between the temperatures mentioned. A small but gradual increase in porosity occurs between 600° and 1100°, and then the porosity rapidly decreases. The porosity range is small and does not permit of a very wide range of application of the clay.

(20) *Stourbridge* B.—Light grey in the raw state, this clay changes to a pink tint at 600°, and this tint deepens up to 1200°, when the colour changes to cream and darkens to buff at 1400°. Although plastic and easy to work, it has only a low binding power. The similarity in chemical composition between this clay and No. 9 is scarcely borne out by the binding power. However, the shrinkage is somewhat similar, increasing very slowly and continuously and rendering firing easy. The porosity shows a steady increase from 600° to 1000°, and then decreases at a very similar rate to 1400°, the porosity being only 2 per cent. less at 1400° than it is at 600°, and the total range is comparatively small.

(21) *Stourbridge* C.—The colour changes are similar to those which occur in the case of Stourbridge *B*. The clay is not at all difficult to work, but will not bind, and tends to split easily.

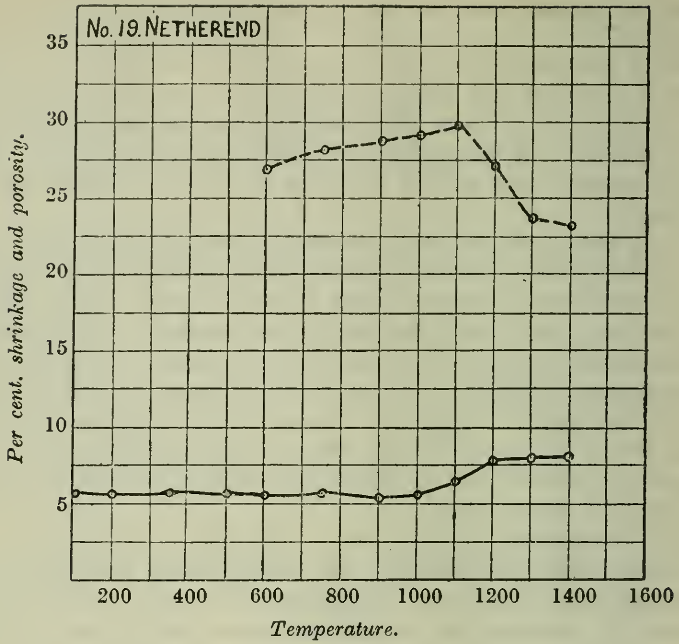
No. 19. NETHEREND
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 19.

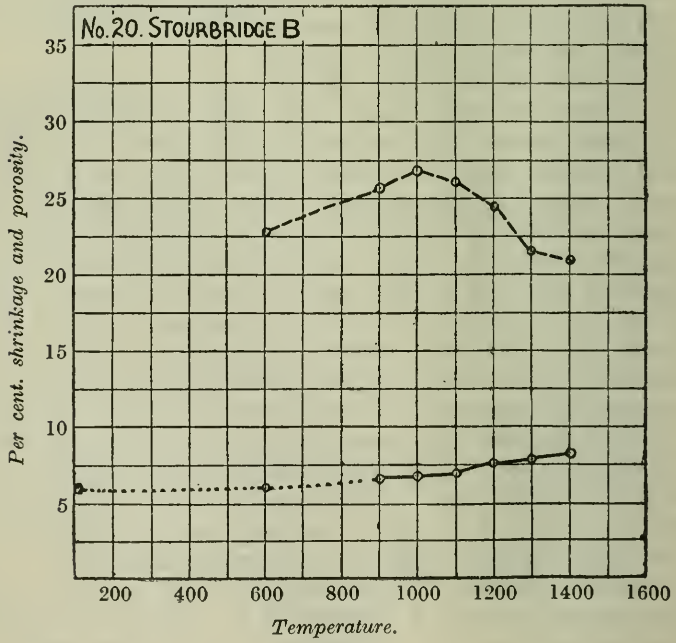
No. 20. STOURBRIDGE B
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 20.

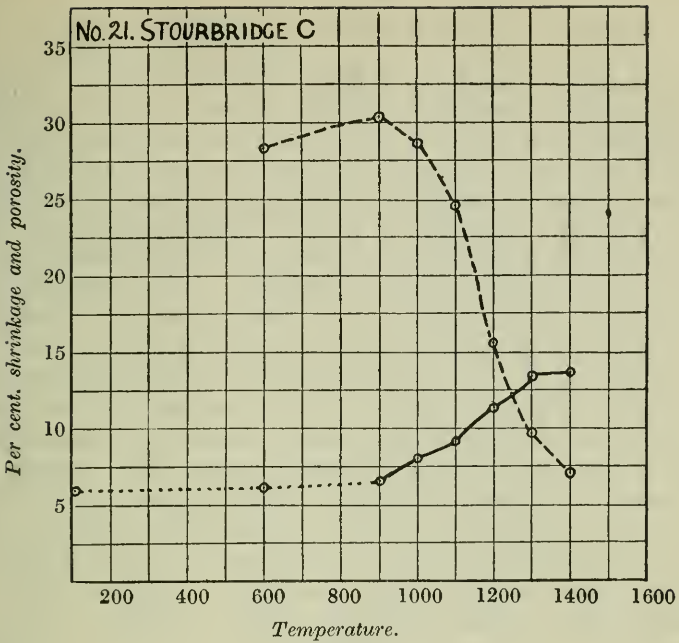
No. 21. STOURBRIDGE C
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 21.

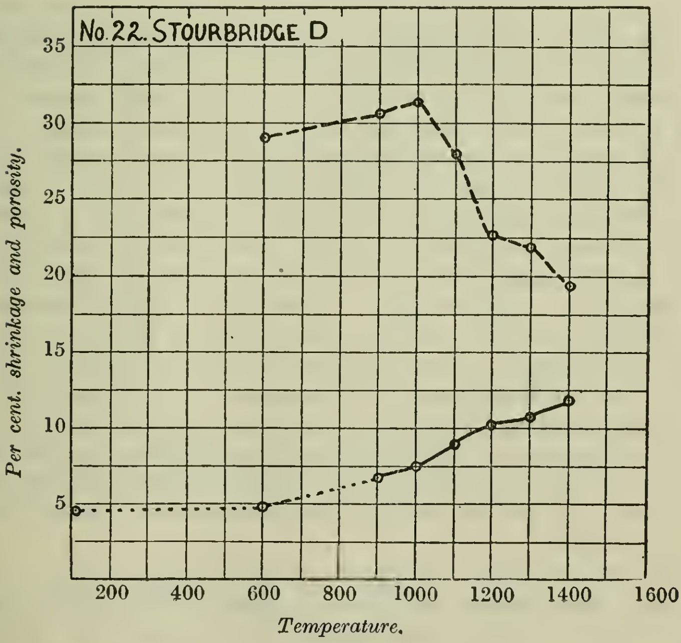
No. 22. STOURBRIDGE D
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 22.

The shrinkage is slight up to 900°, and then a rapid and uniform increase occurs up to 1300°. Firing will not be easily and quickly accomplished with this clay owing to this rapid contraction. The porosity slightly increases to a maximum at 900°, and then decreases extremely rapidly to 1400°, giving a total porosity range of 23 per cent. This clay is quite a likely base clay, the silica and alumina contents bringing it within Grade III limits, and its porosity range offers distinct possibilities. The alkali and iron contents are rather high, but it is possible that care in selection and weathering might bring these within the limits specified.

(22) *Stourbridge* D.—A dark grey clay becoming almost black when wet. It is most difficult to work, particles will not adhere, and when wet the clay is gritty both to touch and in appearance.

From 600° to 1400° the shrinkage increases fairly rapidly and uniformly. The porosity shows a slight increase from 600° to 1000°, and then begins to decrease very rapidly. When determinations are made at a higher temperature, it is possible that the porosity range will be quite substantial. The iron oxide and alkaline earth contents are slightly high for a Grade II clay, but otherwise this clay may make quite a useful base clay, and a little treatment might improve it considerably.

(23 and 24) *Stourbridge* E *and* F.—The chemical compositions of these clays are very similar, No. 23 having higher percentages of fluxes and alumina than No. 24, and a correspondingly lower percentage of silica. Both clays are quite plastic, smooth, and easy to work, No. 24 being the better clay in these respects. To a certain extent, the changes of size and porosity correspond. There is very little shrinkage from 110° to 900°, a fairly steady increase to 1200°, very slight change from 1200° to 1300°, and a somewhat sharp increase from 1300° to 1400°. The porosity increases from 600° to 900° remains steady from 900° to 1000° and then rapidly decreases from 1000° to 1400°. However, the rate of decrease of porosity from 1000° to 1400° is much greater in the case of No. 24. This may possibly be due to the slightly greater amount of fluxes in No. 24, but there is no sign of softening or overfiring at 1400°. Generally speaking, these clays are quite useful, but some care will be necessary in firing both clays, particularly between 900° and 1400°, where the shrinkage is considerable and not particularly uniform. No. 24 possesses an advantage over No. 23 in its greater porosity range.

(25) *Stourbridge* G.—No. 25 is not a really difficult clay to work, but it is rather short. At 1300° it develops the speckled appearance noted in certain other clays. The shrinkage and porosities are very erratic, and these are bound to limit the sphere of useful-

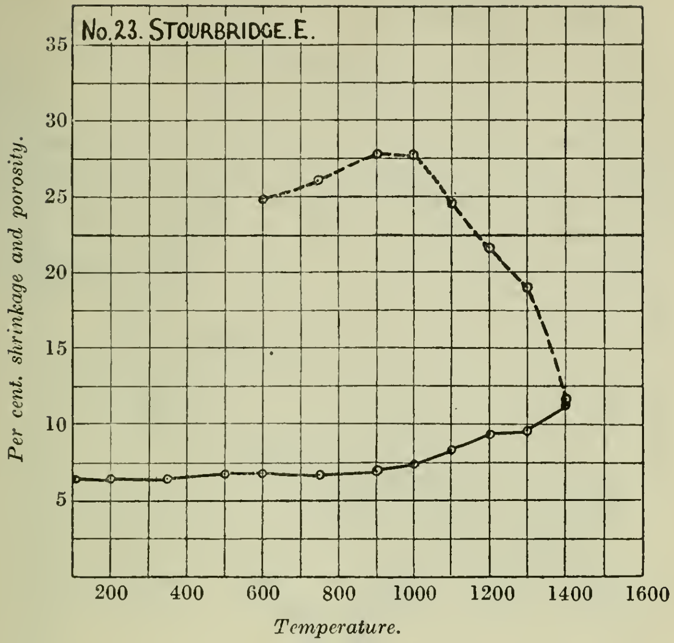
No. 23. STOURBRIDGE. E.
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 23.

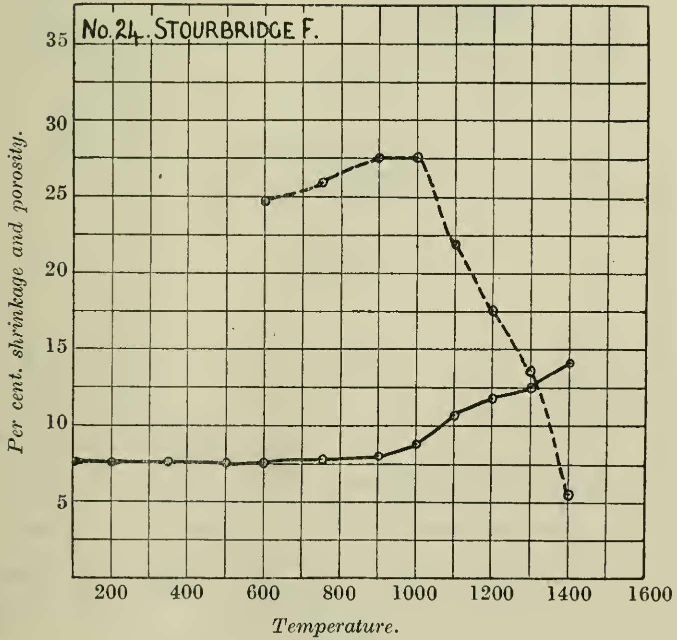
No. 24. STOURBRIDGE F.
Per cent. shrinkage and porosity.
35
30
25
20
15
10
5
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 24.

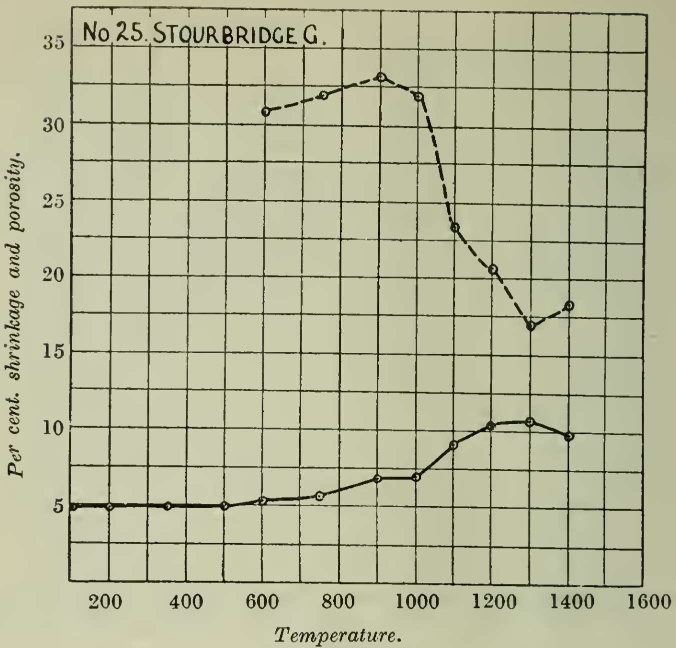
No. 25. STOURBRIDGE G.
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 25.

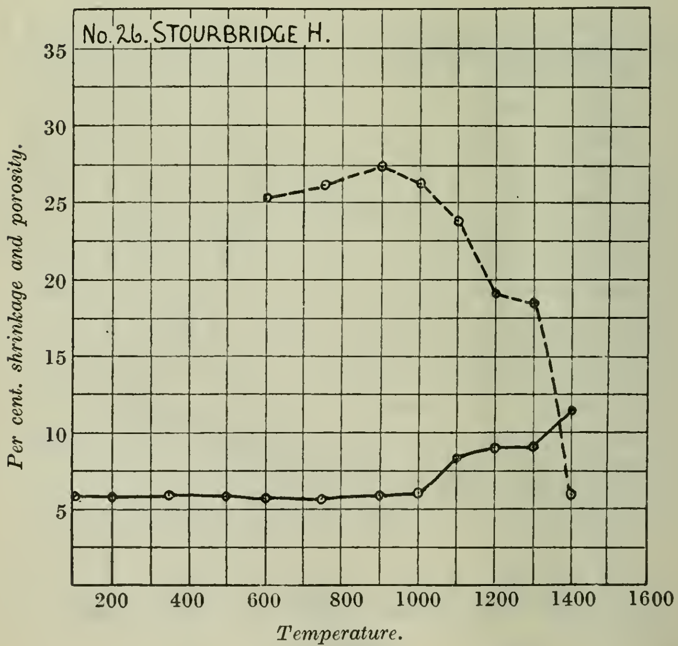
No. 26. STOURBRIDGE H.
35
30
25
20
15
10
5
Per cent. shrinkage and porosity.
200
400
600
800
1000
1200
1400
1600
Temperature.

FIG. 26.

ness of the clay. A small, steady shrinkage occurs up to 750°, and there is a sharp increase between 750° and 900°. There is no change to 1000°, but up to 1200° a very rapid increase occurs. After little change from 1200° to 1300°, there is a notable expansion between 1300° and 1400°, but there was no apparent softening of the clay as a whole. The porosity reaches a high maximum at 900°, decreases rapidly to 1300°, and then an increase occurs corresponding to the expansion between 1300° and 1400°. The porosity range is considerable, but the short nature of the clay, combined with the very erratic behaviour on firing, will tend to produce cracks in articles made from it unless extreme care and considerable time are taken.

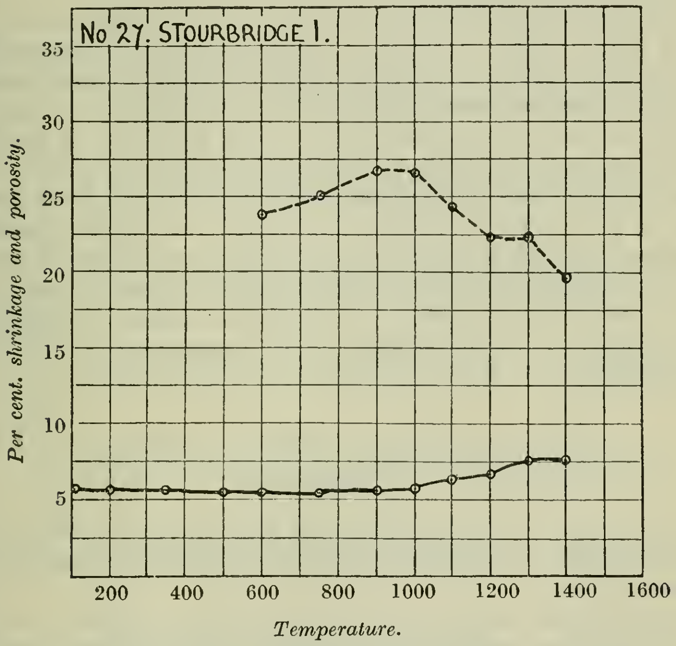

Fig. 27.

(26) *Stoürbridge* H.—This clay is very smooth, plastic, and easy to work, very similar to No. 24. From 110° to 750° there is no shrinkage; on the contrary, a slight expansion occurs. Then there is a steady, uniform shrinkage to 1000°, followed by a very pronounced contraction between 1000° and 1100°. A small but distinct increase in shrinkage occurs between 1100° and 1200°, little or no change between 1200° and 1300°, and then a very

sharp increase between 1300° and 1400° similar to that between 1000° and 1100°. The steady nature of the clay between 110° and 1000° was distinctly promising, but the large and uneven shrinkage between 1000° and 1400° must detract from the value of the clay. The porosity range is considerable, an increase from 600° to a maximum at 900° being followed by a very rapid fall to 1400° of about 22 per cent., half of this decrease occurring between 1300° and 1400°. Despite this rapid change, there is no indication of softening or fluxing.

(27) *Stourbridge* I.—Compared with No. 26, clay No. 27 contains approximately 4 per cent. more silica and correspondingly less alumina, otherwise it is very similar. It would appear scarcely probable that the comparatively small difference in composition could have any considerable effect on the behaviour of the clays on firing; yet the extremely steady and small shrinkage in the case of No. 27 stands out in marked contrast to the much greater and more erratic shrinkage of No. 26. As against the large porosity range of No. 26, the change in porosity in the case of No. 27 is small and much more regular. A smooth and quite plastic clay, No. 27 offers no difficulty as regards working and firing, but its porosity range, at any rate up to 1400°, is not extensive.

SUMMARY OF DATA AND GENERAL DISCUSSION.

The Shrinkages.

Table VII contains the numerical results of the determinations of contraction on drying at 110° and firing at a long series of temperatures.

It will be seen that, as a rule, the shrinkage undergoes but little change until a temperature of at least 750° has been attained, that is, until the uncombined water has been removed. Comment on the rate of shrinkage of each clay has already been made in the previous section, but one point, common to a large number of clays, has not previously been dealt with. It is that shrinkage is not continuous over the range 0—750° or 0—900°, and that there may even be expansion and not contraction. Clay No. 8, for example, expands slightly between 110° and 750°, the shrinkage reaching a minimum at the latter temperature. Clay No. 9 undergoes slight expansion from 110° to 600°.

With clay No. 13 there is slight expansion from 110° to 350°, a distinct shrinkage between 350° and 500°, followed by a marked expansion to 900°. Such alternating changes are detrimental. No. 16 also displays irregularities.

Table VII.

Drying and Firing Shrinkages.

No. of Clay.	110°.	200°.	350°.	500°.	600°.	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.
1	6·90	7·02	7·07	7·29	7·38	7·46	8·99	10·33	11·13	13·60	14·98	15·44
2	6·40	6·44	6·49	6·59	6·87	6·74	6·97	9·05	10·06	13·35	13·81	14·31
3	5·23	5·33	5·43	5·43	5·71	5·77	5·87	7·36	7·90	12·29	11·56	11·44
4	3·92	3·94	3·98	4·07	4·52	5·16	5·55	7·28	7·39	8·75	11·54	11·57
5	4·95	5·00	5·01	5·02	5·03	4·99	5·33	5·37	5·98	7·28	8·05	8·83
6	4·20	4·19	4·19	4·21	4·17	4·06	4·23	4·73	4·92	6·54	7·04	7·66
7	3·31	3·27	3·25	3·25	3·42	3·78	4·26	4·76	5·18	6·73	7·05	7·17
8	6·87	6·85	6·81	6·70	6·63	6·64	6·69	6·82	7·58	7·61	8·11	8·61
9	8·60	8·59	8·58	8·46	8·48	8·61	8·86	8·96	9·17	9·90	10·62	11·24
10	7·16	7·17	7·17	7·18	7·02	7·15	7·13	7·99	8·93	11·04	10·92	11·50
11	7·16	7·20	7·24	6·75	6·94	7·03	6·89	7·32	7·38	7·68	8·59	8·62
12	6·99	7·08	7·14	6·92	6·98	6·94	7·00	7·14	7·46	7·75	8·57	8·79
13	5·86	5·80	5·76	5·86	5·78	5·71	5·64	6·17	6·76	7·80	8·88	9·07
14	6·70	6·80	6·66	6·75	6·80	6·78	6·87	6·96	7·83	9·72	11·07	13·13
15	8·15	8·17	8·06	7·94	8·10	7·88	7·87	8·24	8·66	9·71	9·89	11·97
16	8·12	8·10	7·99	8·11	7·88	8·21	7·96	7·96	8·44	9·07	9·17	11·75
17	5·91	6·03	5·82	6·05	5·84	5·80	6·01	6·80	8·32	11·58	11·97	11·97
18	4·82	4·82	4·85	5·00	5·34	5·45	5·50	6·36	6·67	8·98	9·80	12·06
19	5·57	5·61	5·67	5·61	5·59	5·64	5·42	6·02	6·47	7·85	8·66	8·86
20	5·91	—	—	—	5·93	—	6·38	6·62	6·76	7·41	7·60	7·99
21	5·85	—	—	—	6·19	—	6·62	8·03	9·12	11·40	13·36	13·64
22	4·45	—	—	—	4·68	—	6·64	7·39	8·91	10·20	10·75	11·71
23	6·48	6·48	6·47	6·71	6·73	6·60	7·11	7·47	8·40	9·42	9·68	11·26
24	7·51	7·53	7·54	7·55	7·58	7·75	8·18	8·81	10·73	11·79	12·54	14·28
25	4·80	4·81	4·85	4·90	5·32	5·58	6·87	7·02	9·18	10·43	10·76	9·70
26	5·88	5·88	6·02	5·90	5·80	5·74	6·14	6·28	8·27	9·22	9·28	11·64
27	5·57	5·55	5·54	5·44	5·43	5·38	5·55	5·81	6·34	6·72	7·58	7·64

Although expansion over a considerable range is not a feature of all the clays, there is, with most of them, one temperature below 900° at which a sudden expansion occurs. With one clay (No. 15) the arrest in the regular shrinkage occurs at 500°; with No. 10 the break is at 600°; Nos. 2, 5, 6, and 17 show it at 750°; and Nos. 11, 13, and 19 show it at 900°. These changes are most likely to be connected with allotropic changes in the free silica (quartz) present, and it will be noted that in the few cases where the shrinkage increases regularly, the clays are rich in alumina, although not all the highly aluminous clays show quite regular shrinkage. Clays Nos. 1, 3, 4, and 18, however, furnish examples.

In selecting a clay by virtue of its shrinkage, there are three desirable properties it should possess: (1) Small initial shrinkage; (2) slow and regularly increasing shrinkage up to 750° or 900°; (3) as small and as regular a change in the shrinkage as possible after 750° or 900°. Compromising between these various factors, the following appear (from the point of view of shrinkage only) to be the ten best clays: Nos. 5, 6, 7, 8, 11, 12, 19, 20, 23, and 27.

The Porosities.

Turning now to the porosities, these are stated in detail in Table VIII:—

TABLE VIII.

Clay No.	600°.	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°
1	28·4	30·6	30·9	27·4	25·7	18·2	11·3	8·0
2	28·8	30·4	31·2	28·2	26·6	18·7	14·0	10·2
3	31·7	33·2	32·6	29·3	26·8	18·8	15·9	12·5
4	34·2	35·1	34·9	34·7	33·4	31·9	28·5	25·8
5	26·5	27·1	29·6	28·8	28·7	24·7	24·5	18·1
6	28·6	32·2	30·3	32·4	32·2	26·6	26·8	23·3
7	33·3	36·6	36·6	36·7	35·6	33·6	33·5	31·8
8	18·2	23·5	22·6	21·7	21·5	21·4	20·0	17·6
9	21·7	27·4	27·2	24·9	23·9	22·4	20·3	18·8
10	24·6	29·5	27·9	28·1	25·3	20·3	18·6	12·8
11	24·9	27·0	26·6	27·0	26·7	27·6	27·3	24·9
12	22·9	25·7	25·8	27·0	27·0	27·0	25·4	24·0
13	23·7	26·9	26·7	26·7	26·0	25·6	23·1	19·8
14	30·2	30·8	27·6	26·8	25·3	22·6	17·0	5·2
15	27·7	27·3	26·3	26·9	26·4	25·3	23·5	16·2
16	25·1	26·9	24·8	24·7	25·4	23·7	23·2	20·2
17	28·7	29·5	29·3	27·9	24·9	12·7	11·3	5·9
18	26·4	28·5	28·6	29·4	28·6	23·2	20·6	13·1
19	26·8	28·1	28·7	29·1	29·8	27·1	23·8	23·3
20	22·6	—	25·4	26·5	25·8	24·2	21·3	20·7
21	28·3	—	30·4	28·6	24·6	15·5	9·7	7·2
22	28·8	—	30·4	31·2	27·8	22·6	21·7	19·3
23	24·9	26·2	27·8	27·7	24·7	21·8	19·0	11·6
24	24·8	26·1	27·5	27·6	22·0	17·7	13·7	5·6
25	30·8	32·0	33·0	32·0	23·5	20·9	17·0	18·3
26	25·3	26·3	27·4	26·3	23·8	19·2	18·5	6·0
27	23·9	25·1	26·8	26·6	24·4	22·3	22·3	19·7

Although, undoubtedly, the most useful clay is one with a wide range of porosity, a clay is not to be rejected because of short porosity range. Both high and low porosity may be desirable, according to circumstances. In Table IX an attempt is made to group the clays according to the particular value of the porosity shown at different temperatures.

TABLE IX.

Classification by Porosity.

High Porosity.	Low Porosity.
No. 4. Ayrshire bauxitic.	No. 8. Leeds best pot clay.
No. 7. Kilwinning aluminous shale.	

Wide Range.	Medium Range.	Short Range.
No. 1. Mansfield.	No. 22. Stourbridge *D*.	No. 7. Kilwinning.
2. Kilwinning.	15. Halifax, No. 5.	4. Ayrshire.
3. Coalbrookdale.	23. Stourbridge *E*.	9. Leeds.
14. Halifax, No. 4.	5. Kilmarnock.	11. Halifax, No. 1.
18. Armadale.		12. Halifax, No. 2.
21. Stourbridge *C*.		19. Stourbridge *A*.
10. Grossalmerode.		20. Stourbridge *B*.
17. Ruabon.		16. Halifax, No. 6.
24. Stourbridge *F*.		8. Leeds.
26. Stourbridge *H*.		13. Halifax, No. 3.
25. Stourbridge *G*.		6. Wortley.
		27. Stourbridge *I*.

The clays of exceptionally high porosity (Nos. 4 and 7) are both rich in alumina. It is of interest also to note that those of wide range also have a high or moderately high alumina content, the exception being No. 10, which is very siliceous. Of the clays described as of short range, eight are siliceous and four aluminous clays.

It seemed of interest to ascertain how far both the shrinkage and the change of porosity were affected by the amount of the fluxes present in the clay. In order to ascertain if any relationship existed, therefore, a comparison is made in Table X (p. 200) of the percentage of fluxes present in the ignited clay and the alteration of shrinkage which takes place between temperatures 750° and 1400°, and also the change in porosity.

The fluxes included in the term "total fluxes" for the purpose of this comparison are lime, magnesia, potash, and soda. In a reducing furnace undoubtedly also iron oxide would have to be regarded as a flux, since ferrous oxide, which is readily produced from the ferric oxide, so very quickly reacts with silica to produce ferrous silicate. The samples of clay in our experiments were, however, fired in an electric furnace in the presence of air, and no reduction would be likely to take place; indeed, any iron oxide initially present as ferrous oxide would, it is assumed, be converted to ferric. The effective fluxes were considered, therefore, to be the four oxides named.

As already seen from the results, distinct shrinkage does not take place before approximately a temperature of 750°, and it is assumed that the fluxes would scarcely be active before 750° or 900°. For the purpose of comparison, therefore, the changes in the shrinkage between 750° and 1400° have been taken as the basis. In the case of the porosities, the range considered is not that from 600°, the initial temperature, to 1400°, the final value, since in several cases the porosity rises considerably and reaches a maximum in the neighbourhood of 900°. The change of porosity, therefore, for the purpose of the comparison is that between the maximum porosity and the value at 1400°.

Table X.

Effect of Fluxes on Shrinkage and Porosity.

Clay No.	Total fluxes.	Shrinkage (750—1400°).	Maximum porosity change.
17	4·24	6·17	23·6
21	3·71	7·02*	23·2
2	3·05	7·67	21·0
3	2·89	5·67	20·7
25	2·62	4·12	16·0
1	2·58	7·98	22·9
13	2·44	3·36	7·1
14	2·42	6·35	25·6
18	2·33	6·61	16·3
6	2·16	3·60	9·1
24	2·10	6·53	22·0
22	2·02	5·07*	11·9
5	1·97	3·84	11·5
19	1·94	3·22	6·5
15	1·91	4·09	11·1
27	1·89	2·26	7·1
9	1·80	2·63	8·6
26	1·80	5·90	21·4
10	1·74	4·35	16·7
8	1·70	1·97	5·9
20	1·64	1·61*	5·8
16	1·59	3·54	6·7
12	1·58	1·85	4·1
7	1·57	3·39	4·9
23	1·15	4·66	16·2
11	1·14	1·59	2·7
4	0·69	6·41	9·2

* 900—1400°.

It will be seen that there is, broadly, a connection between the proportion of fluxes and the shrinkage, and also between the amount of fluxes and the change of porosity, but the relationship is by no means clear-cut or free from exceptions. Considering the shrinkages, it will be seen, however, that for the most part the clays with a high shrinkage have total fluxes exceeding 2 per cent., whilst the majority of the clays having less than 2 per cent. total fluxes have a comparatively small shrinkage.

Much the same conclusion is to be drawn in connection with the change of porosity. At the head of the table, that is, in the case of the clays with a rather high percentage of total fluxes, the change of porosity is great. On the other hand, the clays which are comparatively free from fluxes undergo in most cases no great change of porosity. Notable exceptions in the case of shrinkage and porosity to the preceding generalisations are clays Nos. 13, 6, 26, 10, and 23. The general results, however, do indicate that a reduction in the total fluxes, as, for instance, by subjecting the clay to weathering, may be expected to reduce the shrinkage which the fired clay article undergoes. On the other hand, the range of porosity may be expected to be modified by artificially varying the amount of the total fluxes. The results suggest, indeed, that a clay with only a small porosity range may have that range increased by the addition of fluxes, such as possibly by the addition of felspar.

The Apparent Specific Gravity.

By the "apparent" specific gravity is meant the specific gravity of the slab as a whole, inclusive of material and pores. The test does not shed any new light on the properties of the clay not shown by the porosity and shrinkage tests. A little consideration will show that the change in value of the apparent specific gravity depends on the changes in the shrinkage and porosity. Both shrinkage and diminution of porosity result in increased apparent specific gravity, reinforcing one another in this respect. Clays 1, 2, 3, and 14 all exhibit a well-marked shrinkage on being fired, and the change in the porosity is still greater, so that the apparent specific gravity rises unmistakably. Again, if the porosity range is short but the amount of shrinkage great, the apparent specific gravity will also increase, as in the case of the Ayrshire bauxitic clay (No. 4). Where both the shrinkage and the change of porosity are small over the firing range, the apparent specific gravity undergoes but little change. Clays 11 and 20 are examples.

Further confirmation of these facts can be obtained by comparing the table of apparent specific gravities (Table XI) with the shrinkages and porosities.

TABLE XI.

Clay No.	600°.	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.
1	1·76	1·76	1·81	1·93	1·97	2·15	2·24	2·30
2	1·73	1·76	1·76	1·80	1·91	2·08	2·20	2·24
3	1·69	1·70	1·70	1·86	1·90	2·09	2·04	2·06
4	1·70	1·72	1·74	1·84	1·83	1·91	2·06	2·14
5	1·82	1·81	1·86	1·85	1·86	1·94	2·00	2·06
6	1·74	1·75	1·76	1·78	1·79	1·91	1·89	1·94
7	1·68	1·67	1·73	1·72	1·74	1·80	1·81	1·86
8	1·94	1·95	1·96	1·97	1·97	1·98	2·00	2·01
9	1·72	1·87	1·89	1·72	1·80	1·93	1·97	1·96
10	1·89	1·86	1·86	1·87	1·95	2·04	2·06	2·10
11	1·88	1·85	1·84	1·85	1·85	1·86	1·90	1·91
12	1·89	1·87	1·86	1·85	1·86	1·86	1·91	1·92
13	1·83	1·80	1·80	1·81	1·83	1·86	1·94	1·99
14	1·73	1·71	1·72	1·77	1·82	1·91	2·03	2·20
15	1·81	1·82	1·81	1·82	1·84	1·87	1·88	2·03
16	1·88	1·85	1·85	1·86	1·86	1·88	1·90	1·97
17	1·82	1·81	1·81	1·86	1·94	2·21	2·24	2·22
18	1·77	1·78	1·79	1·83	1·86	1·98	2·09	2·21
19	1·86	1·82	1·81	1·83	1·84	1·92	1·98	1·99
20	1·93	—	1·91	1·91	1·92	1·96	1·99	1·99
21	1·82	—	1·81	1·86	1·96	2·11	2·25	2·27
22	1·77	—	1·80	1·83	1·86	2·01	2·03	2·10
23	1·87	1·86	1·86	1·88	1·94	2·00	2·03	2·14
24	1·86	1·86	1·86	1·89	2·01	2·10	2·15	2·28
25	1·71	1·73	1·73	1·79	1·92	2·02	2·06	1·90
26	1·87	1·85	1·85	1·87	1·96	2·03	2·03	2·24
27	1·91	1·89	1·89	1·91	1·95	1·96	1·94	1·96

The Specific Gravity of the Clay Material.

In this property the effect of the pores is eliminated and only the solid material considered. Table XII sets out the results. Practically no general deductions can be drawn from them. Very little change in the real density of the clay takes place. In two cases there is quite a distinct rise, namely, in clays 4 and 7. Both are aluminous, the first-named very aluminous; but, on the other hand, so are 1, 2, 3, 17, and 22, which behave quite differently.

The complex character of most clays makes it not easy to foretell how the actual specific gravity should change. Felspar after being fired to a high temperature undergoes increase in volume; so also does free quartz or silica. On the other hand, the presence of fluxes may tend to bring about contraction. The actual effect of this combination of circumstances will depend on the relative proportions of each constituent of the clay. From an examination of its composition, clay No. 4 appears to be simple, containing no free silica, very little felspar, and a very small proportion of fluxes. One would expect, in this case, that increase of density would occur after being fired.

TABLE XII.

Clay No.	600°.	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.
1	2·45	2·53	2·61	2·65	2·65	2·63	2·53	2·50
2	2·46	2·52	2·55	2·66	2·55	2·56	2·55	2·50
3	2·48	2·53	2·56	2·63	2·59	2·58	2·43	2·35
4	2·57	2·64	2·67	2·82	2·75	2·79	2·88	2·88
5	2·48	2·49	2·61	2·60	2·62	2·57	2·64	2·53
6	2·45	2·58	2·53	2·63	2·64	2·57	2·59	2·53
7	2·53	2·63	2·74	2·72	2·70	2·71	2·72	2·72
8	2·40	2·54	2·53	2·52	2·52	2·53	2·49	2·43
9	2·43	2·55	2·59	2·30	2·38	2·48	2·47	2·41
10	2·51	2·64	2·63	2·61	2·60	2·56	2·53	2·41
11	2·50	2·54	2·50	2·53	2·54	2·57	2·61	2·54
12	2·45	2·52	2·50	2·53	2·54	2·55	2·56	2·52
13	2·40	2·47	2·45	2·49	2·48	2·51	2·52	2·48
14	2·47	2·48	2·37	2·41	2·43	2·48	2·45	2·34
15	2·50	2·50	2·45	2·47	2·50	2·50	2·51	2·42
16	2·50	2·52	2·45	2·47	2·49	2·48	2·47	2·45
17	2·55	2·57	2·56	2·59	2·58	2·52	2·49	2·37
18	2·47	2·50	2·51	2·60	2·60	2·58	2·61	2·53
19	2·53	2·55	2·56	2·62	2·63	2·63	2·60	2·59
20	2·50	—	2·55	2·58	2·58	2·57	2·54	2·51
21	2·53	—	2·59	2·57	2·50	2·50	2·50	2·44
22	2·50	—	2·60	2·64	2·57	2·57	2·63	2·62
23	2·48	2·50	2·57	2·60	2·58	2·54	2·51	2·46
24	2·47	2·50	2·58	2·60	2·58	2·54	2·50	2·42
25	2·48	2·51	2·60	2·62	2·52	2·50	2·46	2·33
26	2·50	2·52	2·55	2·60	2·56	2·51	2·49	2·38
27	2·52	2·52	2·58	2·60	2·58	2·52	2·50	2·44

Application of the Results to Prepared Clays.

It may be argued that as all refractory goods are usually made up of a mixture of clays in addition to grog, the results recorded in this paper are of less practical than theoretical importance. This, however, is not the case. For whilst it is possible to vary the shrinkages and porosities at will, within certain limits, by judicious mixtures of different clays, it nevertheless remains true that the actual effect produced is but an average one dependent on the amount of each clay present in the mixture. Hence it should be possible to foretell, approximately, from the results reported, what properties of shrinkage, porosity, and specific gravity may be obtained in any known mixture. We have already made tests over the whole range of temperature on mixtures of three clays and grog, and the results confirmed what we predicted from the behaviour of the single clays.

Summary.

1. Twenty-seven different clays, drawn from various sources in England, Wales, and Scotland, have been chemically analysed, measurements have been made of their shrinkages, porosities,

apparent and actual densities after being fired at a long series of temperatures up to 1400°, and information has been gained concerning their working properties and their colour changes when fired.

2. No definite relation appears to subsist between the amount of water required to produce a suitable working consistency of a ground clay consisting of a varying mixture of particles all of which pass through a 30-mesh sieve and the chemical composition of the clay.

3. So far as can yet be ascertained, there does not appear to be any definite relationship between the size of the clay particle and the amount of water needed for working consistency.

4. From the chemical composition obtained by analysis, the possible mineral composition was calculated by the method of H. S. Washington. The results do not lead to any possibility of correlating the physical properties determined with the calculated mineral composition.

5. Of the twenty-seven clays examined, only five have compositions which come within the requirements of the Provisional Specification issued by the Refractories Research Committee of the Society of Glass Technology, and of the five, one (No. 4) nearly reaches the standard for a Grade I clay, provided the titanium oxide present is harmless, and the four others (Nos. 19, 23, 24, and 26) meet the requirements only of Grade III.

6. The classification of clays in grades according to their chemical composition appears to the authors to be premature. It is suggested that it would be more suitable at present to classify the clays on the basis of their shrinkage and porosity, having regard to their iron oxide content (and naturally also to their refractoriness, a property with which this paper has not dealt). How far these criteria are related to resistance to actual wear and tear in a furnace has yet to be determined.

7. Clays having approximately similar chemical composition usually have similar working properties, but their shrinkages and porosities are not necessarily similar, and, indeed, may differ greatly.

8. The approximate order of binding power possessed by the different clays as tested by small scale experiments is set out (p. 174).

9. The aluminous clays are frequently not easy to work. Thus, Coalbrookdale, Ayrshire, Armadale, and Stourbridge *D* are rather short, whilst Ayrshire and Kilwinning aluminous shale tend to develop cracks on drying. The siliceous clays are, generally speaking, easy to work.

10. The majority of the clays tested exhibit expansions at some point of the firing range, 500—900°, this expansion probably having connection with the allotropic changes occurring in the free silica present. The clays in which continuous shrinkage occurs are rich in alumina.

11. Generally speaking, the clays showing a wide range of porosity have a high or moderately high alumina content, together with a considerable proportion of the fluxes lime, magnesia, potash, and soda, whilst those of short range are siliceous. Notable exceptions occur.

12. Clays containing more than 2 per cent. total of the fluxes lime, magnesia, potash, and soda usually exhibit marked shrinkage when fired above 750° and have a wide range of porosity. Clays containing less than 2 per cent. total fluxes have a smaller shrinkage and porosity range, dependent on the amount of the fluxes. Distinct exceptions to both statements occur, but, usually, shrinkage and porosity change vary with the proportion of fluxes. It appears likely, therefore, that the range of porosity of a clay could be extended by the addition of fluxes, as, for example, in the form of felspar.

13. The apparent specific gravities depend on the relative change in the porosity and the specific volume (shrinkage) of the clay.

14. The actual density of a fired clay depends on a number of factors the effect of which it is not easy to determine.

15. From the tables of shrinkage, porosity, and apparent specific gravity of the individual clays, it is possible, approximately, to predict what shrinkage, porosity, and apparent specific gravity a mixture of clays, with or without grog, will have when fired to a definite temperature within the range 110—1400°.*

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XVII.—*On a New Type of Gas-fired Furnace.*

By Dr. Morris W. Travers, F.R.S.

(*Read at the Sheffield Meeting, February 18th*, 1920.)

I.

Improvements in technical processes have often arisen out of purely accidental circumstances, though it is sometimes difficult to determine whether to credit a discovery to chance or to insight born of practical experience. Generally speaking, however, the question of accident or direct intention is of little importance, and it is better to concentrate attention upon the development of an idea than to waste time in investigating it's origin.

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* The discussion on this paper will be printed in No. 15 of the Journal. Contributions are invited.

In the glass works in which the Dennis Simplex Furnace originated there were, up to the middle of last year, furnaces of two types. Three of the furnaces were so-called direct-fired furnaces, fitted with Frisbie under-feed arrangements, by means of which the fuel is fed from below into the middle of the grate, which is at the bottom of a well in the centre of the furnace. The fuel is largely gasified, and partly burned on the grate, and the gases pass over and between the pots, through flues in the pillars which support the crown, and thence into the circular stack which rises above the furnace. For obvious reasons the fuel efficiency of these furnaces is very low. There was also a gas-fired furnace of a Continental pattern, with two producers built into the centre of it, and flanked by recuperators. The gas from the producers rose through a central eye, meeting the hot secondary air from the recuperators at a little distance below the siege. The pots, eight in number, stood in a circle about the eye, and the products of combustion passed between the pots, through openings in the pillars supporting the crown, and thence, downwards, into flues leading to the recuperators. The general arrangements of such furnaces have been fully described by other authors in the JOURNAL. In this furnace very intense combustion took place in the eye and behind the pots, and for this and for other reasons, the furnace did not prove a satisfactory one. Finally one of the flues collapsed, one of the recuperators became full of glass, and the furnace was put out of action.

It was decided not to rebuild the furnace, but as there was an urgent demand for glass, the management decided, at all events as a temporary measure, to reconstruct it, replacing the producers, which were to be cut away entirely, by a Frisbie under-feed grate. This work was carried out in July, 1919, and when the furnace was fired up, it was found to work with astonishing efficiency, and to be extremely easy to handle. It had already been at work for about four months when it was brought to my notice, and I was asked to investigate it.

A section through the furnace is shown in Fig. 1, and it will be seen that the grate is fixed below a conical space which tapers upwards to the eye, which is 2 ft. 9 in. in diameter. The grate measures 3 ft. 9 in. by 3 ft. 9 in., and the bars are 6 ft. below the siege. The centre of the grate is occupied by the under-feed arrangement, which consists of a solid frame measuring 2 ft. by

1 ft. 9 in., with a conical cavity through it, 18 in. in diameter at the top and 9 in. deep, through which the fuel is forced by means of a piston, so that after each firing the cylindrical space remains filled with coal. The weight of each charge is from 20 to 25 lb., and about four charges are put up into the furnace every forty-five minutes, the rate of firing being about 130 lb. of fuel per hour. Each charge of fuel is introduced below the partly gasified fuel of the previous charges; and, as in the case of the Jones underfeed grate, which was investigated by the American Bureau of Mines (see p. 211), the products of distillation from the fresh fuel pass through a red-hot layer, and, in the process, the tarry matter and heavy hydrocarbons are to a large extent decomposed. The partly carbonised fuel is pushed outwards over the grate bars, and the coke is gasified by the air passing through it. The depth of the fuel bed is from 6 to 9 in., yet, as will be shown presently, gasification of the fuel is sufficiently complete.

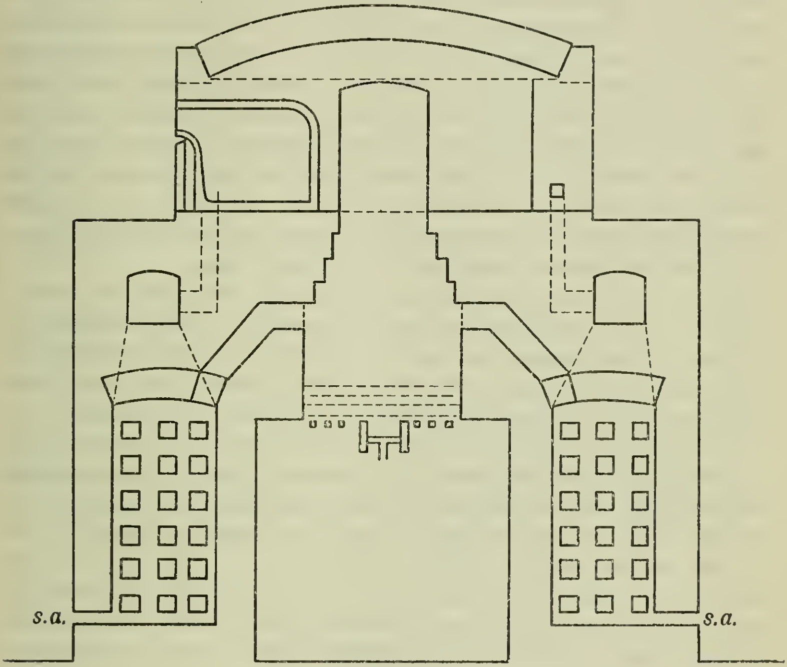

FIG. 1.

The secondary air enters at the sides of the conical space and at a depth of about 2 ft. 6 in. below the eye. However, it seems to be perfectly clear, for reasons which will be explained later, that combustion does not take place below the siege, for the temperature in the conical space is not above a bright red heat, while that of the furnace chamber is a full white heat. Practically no clinker is formed on the grate or about the sides of it. The fire is rarely cleaned more often than once in twenty-four hours, and is not broken up, or indeed touched at all, between the times of cleaning. In cleaning the grate, the stoker takes a light bar with which to separate the fire bars, and then removes the ash and such pieces of clinker as may be formed by means of a hook. After cleaning one side of the grate, the fuel from the centre is spread over the fire bars, and then six charges of fuel are put up into the furnace. Half an hour later the opposite side of the grate is cleaned. After cleaning the grate and firing up, a little smoke may be seen issuing from the stack, but no smoke is given off when the furnace is fired in the ordinary way.

The total weekly consumption of fuel in the furnace, over a period of nine months, has rarely exceeded a total quantity of 9¼ tons. The ashes from each day's firing are mixed with the fuel for the next day, only the stone, clinker, and dust being thrown away. There is practically no waste in the ashes.

With a view to measuring the output from the furnace, which was melting a soda-lead metal for electric lamp bulbs, containing about 33 per cent. of lead oxide, a pot was filled and plained, and the metal ladled and weighed. The ladled metal weighed 13 cwt. As the pot was full of metal to within 1 in. of the lip, and was emptied to within 1½ in. of the bottom (measured with a trying rod), the full pot may be said to contain 14 cwt. of metal; of this it is estimated that 11 cwt. could be worked out. This latter quantity is taken as the output from each pot.

The following tests were made to determine the rate at which metal could be plained in the furnace, and it must be observed that during the operation no adjustments of the air-slides and dampers were made, and the fire was not touched, except to feed it by means of the Frisbie mechanism, and to clean it once in twenty-four hours:—

(*a*) Six pots were filled between 5.30 and 6 a.m. on January 31st, two pots in the furnace being broken. Second and third fillings were put on at 7.30 and 9.30 a.m., and at 4.30 p.m. the stoppers were taken down, when the metal was plain, with a slight large heat boil. As the experiment was carried out at the week-end, the pots had been filled with a mixture of one-third cullet to two-thirds batch.

(*b*) At 11 a.m. on January 23rd two pots were filled, one filling only being put on. During the whole day four pots were being worked from, one pot was full and plain with the stopper down, and one pot was empty and broken. The pots were not touched till 10 p.m., when it was clear that the metal had been plain for some time. It was estimated that about 7 cwt. of metal could be worked out of the pots after a single filling.

(*c*) At 6.15 p.m. on January 23rd a pot was filled with one-third batch and two-thirds cullet, and second and third fillings were put on at 10 p.m. and 1.15 a.m. During the night the next pot in the furnace was empty, and open for use by the tube shop as a glory hole, another was worked all night for tube and rod, a third was filled at 5 a.m., three pots were plain and with the stoppers down, and one pot was broken. At 7.15 a.m. a proof showed that the metal was plain, with a large open boil which would have cleared in an hour. The pot was stoppered again, and at 9.30 it was taken down, when the metal was perfectly plain, and the pot full to within an inch of the lip.

The quality and colour of the metal was in every case excellent.

The furnace was not being worked up to anything like its full capacity, as there were no pits in the floor for the mould machines, and the principal product of the glasshouse was electric lamp bulbs. A certain amount of small bore tube was worked from it, but the demand was limited. It was therefore found possible to work out on the average only about eighteen pots of metal a week, but it will be observed that this number of pots was equivalent to

$$18 \times 11 \text{ cwt., or nearly } 10 \text{ tons,}$$

and taking the coal burned in the furnace as 9 tons 3 cwt. during the whole week, the actual output from the furnace was over 1 ton of metal worked out for 1 ton of fuel consumed.

As the first experiment (*a*) shows that it would be possible to fill every pot in the evening and plain the metal by the morning, the maximum output from the furnace, for five days' working only, may be reckoned at

$$5 \times 8 \times 11 \text{ cwt., or } 22 \text{ tons,}$$

or about 2 tons of metal for every ton of fuel burned. The metal might be worked out at this rate for heavy pressed ware, but if only one filling were put on each night the output would still be

$$5 \times 8 \times 7 \text{ cwt., or } 14 \text{ tons,}$$

nearly $1\frac{1}{2}$ tons of metal for 1 ton of fuel. The problem of turning out over a ton of metal for a ton of fuel consumed in this furnace, making no allowance for broken pot or troubles of any kind, is therefore solved.

Direct-fired furnaces with the Frisbie feed in the same works were burning the following quantities of coal, of better quality, each week, and take longer to plain the metal:—

8 Pot furnace	30 tons.
10 ,, ,, ...	40 ,,
12 ,, ,, ...	nearly 50 ,,

In dealing with the life of pots, it must be remembered that one should consider the service which they render and not merely the time which they are in the furnace. One often hears of pots remaining in a furnace for over a year; but it is generally the case that the furnace is " direct fired," working at a comparatively low temperature, and plaining the metal once a week. In these circumstances there should be no limit to the life of a pot. The nature of the metal must also be taken into account, for while in a high-temperature furnace, melting soda-lime metal, pots may last six months, pots used for lead metal may only last three months.

In a furnace such as the Dennis Simplex, which is worked intensively, the pots should be reset about every three months; and six months' experience shows that the pots will last fully this time. Only on one occasion, when a drunken stoker nearly let the furnace out, and when four pots were lost, has any trouble whatsoever been experienced.

After nine months' working the furnace is in excellent condition. The pots stood, originally, 4½ in. from the edge of the eye, and the eye does not appear to have become enlarged appreciably.

The furnace has given great satisfaction to the workmen, who find it extremely easy to handle and convenient, and to the management, both on account of the fuel economy and the continuity of output.

II.

I have been able to spend a limited amount of time in qualitative rather than quantitative investigations of furnaces, for during the war my attention was entirely devoted to the actual production of the glassware needed by the country, and during the past eighteen months few opportunities for experimental work have presented themselves. The proper study of furnace problems is a matter of rather costly experimental work, and a considerable amount of leisure in which to carry it out. No subject connected with the glass trade would, however, better repay careful study than the glass furnace.

It has been suggested by several glass manufacturers that it is impossible to regard a furnace working with a shallow fuel bed as gas-fired, but this objection cannot be supported. The investigations of the American Bureau of Mines (Bulletin 135, Technical Papers 63, 137, 139) have proved that in a direct-fired furnace, fed with coal, the whole of the oxygen which enters the bottom of the grate is consumed before it has penetrated more than three or four inches into the fuel bed. With a 6-in. fuel bed, when air is admitted both above and below the fire, the gas at the upper surface contains 20 to 21 per cent. of CO and 6 to 7 per cent. of CO_2, which is partly formed by the penetration of air from above. In the case of a Jones mechanical under-feed grate, which is somewhat similar in its action to the Frisbie feed grate, though it is continuous instead of being intermittent, the gas in the upper layers contained 22·3 per cent. of CO and 5·4 per cent. of CO_2. The authors of these papers point out that "the fuel bed in most industrial ~~gas-fired~~ COAL-FIRED furnaces acts as a gas producer."

Wendt's experiments,* carried out with an air-blown commercial gas producer, showed that the CO–CO_2 equilibrium was attained within 10 in. (0·25 m.) of the fire bars, from which it may be concluded that complete gasification of air might be secured with less than a 10 in. bed of coke, provided that it were even and free from holes. Further, during the past year Mr. D. J. Smith has described in the *Journal of the Institution of Automobile Engineers* a gas producer for mechanical transport which works satisfactorily with a 6-in. bed of anthracite or a 7-in. bed of coke. The fact is that, while there is no difficulty in producing a fairly high quality gas when working with a shallow fuel bed, there is great difficulty in securing complete combustion in many direct-fired industrial furnaces, such as the glass furnaces which are in common use in this country. This accounts to a great extent for their low fuel efficiency.

The Dennis furnace works under positive pressure, and the pots are, of course, closed. The only controls are the air slides on the secondary air inlets at the bottom of the recuperators, and the dampers on the flues leading to the stack. There is no control of the primary air, nor is such control needed, for the following reasons. The height from the secondary inlets to the air ports is about 2·5 metres, and as the mean internal temperature of the recuperator is about 400°, the static difference of pressure at the inlet and outlet is about 1·6 mm. of water. The recuperator may be considered as a system of twenty-four tubes 10 cm. in diameter and 6 metres long, so that as the quantity of air passing through them is only 0·1 cubic metre per second, the back pressure due to friction is almost too small to measure. This is confirmed by the fact that, in an attempt to measure the rate of flow of air into the recuperator, every pulsation of the furnace was indicated on the water gauge connected with the Pitot tube placed in the air duct. The height of the air ports above the grate is 1 metre, and as the temperature above the grate is about 1000°, the static pressure of the gas is about 0·9 mm. of water at that level, apart from the dynamic effect of the gas stream already referred to. To maintain a proper balance, it is necessary to check the flow of air by partly closing the air slides, and this is the only regulation necessary on the inlet side of furnace. The recuperator system may be regarded as a means of injecting air into a furnace working under positive pressure. In many furnaces of the Boetius type the secondary air never gets into the furnace at all, for unless the furnace is working under a negative pressure, there is rather a tendency for the furnace gases to flow into the air ports than for the secondary air to enter the furnace.

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* *Stahl und Eisen*, 1902.

We really know very little about the properties of very hot gases. When, as in the common types of recuperative glass furnaces which have recently been built in this country, the hot gas and hot air meet in streams at right angles to one another in a restricted space, or eye, in the centre of the furnace, we know that a condition is set up which is very destructive to the structure of the furnace, and to the pots. The condition is such that the air and gas mix rapidly, so that we have a solid flame, or mass of gaseous matter, in a state of intense chemical activity. Formerly it was supposed that this flame would lose its energy only by conduction, and by radiation from the surface layers. ndar ~~Calendar,~~* however, first showed that a radiating gas is not opaque to its own radiation, and that an ordinary Mêker burner flame will radiate up to 20 per cent. of its total energy, the intensity of radiation increasing with the thickness of the flame. With hot gas and hot air the total energy of the flame will be greatly increased, and the radiation from it may increase more rapidly than the increase in the total energy. The destructive action of the kind of flame referred to on the material of the furnaces and pots is due to the intense radiation from such flames, and not to mechanical "cutting action," which one often hears referred to.

The failure of the pots in such furnaces is generally due to the splitting of the pot exactly in the centre of the back. Radiation from a column of flame rising through the eye on to the convex surfaces of the backs of the pots would be most intense along a vertical line drawn down the back of each pot. This is in accordance with the ordinary laws of radiation. The heat radiated to the backs of the pots would rapidly be conducted to the interior, and used up in effecting chemical change, or in raising the temperature of the contents of the pots. However, as the metal became plain, it would cease to absorb heat rapidly, and the pot material would begin to soften. In actual practice the pots gradually bulge at the back, and ultimately, if the furnace is not "dropped" the moment the metal is plain, they burst.

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* *B.A. Reports,* 1910, p. 214.

The fault of such furnaces is not that the mean working temperature of the furnace chambers is too high, but that the condition, due to the almost instantaneous reaction of the constituent molecules of the air and gas, produces radiation from solid columns of flame, which is extremely local in its action.

To eliminate this so-called "cutting action," furnaces are often designed to produce the effect called long flame combustion. In this case the air and gas flow in parallel streams, and combustion takes place at the interface, and extends through the mass as the gases mix by diffusion. At first we have a thin zone of combustion, and as the radiation from this is dependent to a great extent on its thickness, it is far less in intensity than from the solid flame produced by the two streams meeting at right angles. The radiation effect seems to be largely an instantaneous one, the result of the molecular changes taking place in the flame; so that if combustion takes place only as the stream of air and gas travels across the furnace, the radiation will be distributed along its path. Whether the products of combustion continue to radiate energy to any great extent, or whether they lose heat mainly by conduction, is a matter which is the subject of a good deal of controversy.

One of the most noticeable features of the Dennis furnace was that, even after it had been for some months in use, the blocks which formed the eye had not deteriorated materially. The pots stood originally 4½ in. from the edge of the eye, and after nine months the eye had not become appreciably enlarged. Further, no trouble had been experienced through the pots splitting down the back. This could only be accounted for on the assumption that the streams of air and gas did not mix below the level of the siege, but only after they had passed well within the furnace chamber.

It must be remembered that the fuel is fed into the grate from below the centre of it, and that each charge is partly gasified before the next charge forces it upward and outward over the fire bars. As the fuel is forced outward over the grate it becomes more and more completely gasified, and at the margins consists of carbon with a considerable proportion of ash. The whole of the upper surface is heated by radiation from the brickwork, so that the gas probably leaves the fuel bed at a fairly uniform temperature; but while the gas in the centre is very rich in hydrogen, that at the margin of the grate will be a poor producer gas rich in carbon dioxide. The gas in the centre or axis of the space above the grate will tend to ascend with a higher velocity than the gas near the walls (Fig. 2).

Professor Grume Grjimailo, in his "Essai d'une Theorie des Fours à Flamme," has called attention to the permanence of such gas streams, which can move through the atmosphere of a furnace just as a stream of petrol can ascend through a mass of water, or as a stream of water flows through air. In the present case the narrowing stream of gas may be likened to a stream of water escaping from an opening in the bottom of a tank. No clearer account of the mechanism of this phenomenon is to be found than in the writings of the late Prof. James Thomson, who originally investigated it.

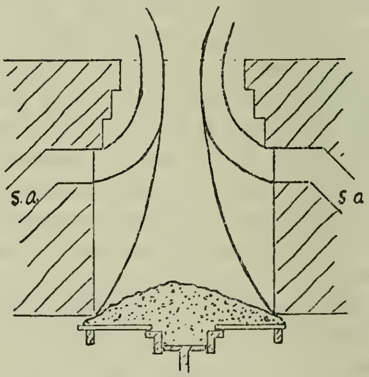

Fig. 2.

The hot secondary air enters the space below the eye at comparatively low velocity, and at some distance from the gas stream, which is then of comparatively small cross section, and is moving with a proportionately increased vertical velocity. It will therefore act as the jet in an injector water pump, which was also first investigated by Prof. James Thomson, and the streams of gas and air will tend to move upward co-axially. Combustion will take place at the interface, but from the thin layer in which chemical action is taking place, the total radiation will be small. It is quite possible that the air and gas do not completely mix till they are actually travelling over and between the pots.

As to whether the heating of the pots is due mainly to radiation or to conduction from the flames, the hot products of combustion, is an open question. If conduction is a very material factor, the rate of heating might be increased by corrugating their surfaces, particularly at the sides, where the streams of gas pass through narrow spaces between them.

III.

The following attempt to account for the manner in which the energy is utilised in a furnace of this type is based upon observations on several furnaces. It is intended to draw attention to the importance of investigation in several directions, and its speculative character must therefore be excused.

The furnace is supposed to be working with a coal of composition:—

	Per cent.		Per cent.
Carbon	79·0	Sulphur	0·5 (neglected)
Hydrogen	4·0	Moisture............	2·0
Oxygen	8·0	Ash	5·0
Nitrogen	1·5		

The dry, ash-free coal has calorific value 8900 K. As 60 kilos. per hour are burnt, the energy utilised in the furnace, allowing for 2 per cent. carbon lost in the ash, will be almost exactly 500,000 K. Supposing that 33 per cent. of the coal is volatile, we have:—

Coke	C	60·0 per cent.	=	3·000 C	Kilo-molecules	per	hour.
Volatile......	C	17·0 ,,	=	0·850 C	,,	,,	,,
	H	4·0 ,,	=	1·200 H_2	,,	,,	,,
	O	8·0 ,,	=	0·150 O_2	,,	,,	,,
	N	1·5 ,,	=	0·032 N_2	,,	,,	,,
	H_2O	2·0 ,,	=	0·067 H_2O	,,	,,	,,
Ash	C	2·0 ,,					
	Mineral	5·0 ,,					

From the results obtained in investigating so-called direct-fired furnaces by the American Bureau of Mines, it appears that the gas at the surface of the fuel bed in an under-fed grate contains CO and CO_2 in the proportion of about 5 to 1. If we assume, therefore, that 20 per cent. of the coke is burned to CO_2, and the balance to CO, we shall obtain a gas approximating to this composition. Using a deep fuel bed in an air-blown gas producer, with no steam, and no water on the bars, though the latter fact is probably immaterial, Wendt [*] obtained a temperature of about 1400° at the point in the fuel bed where the gas contained only a trace of CO_2, probably the theoretical minimum. This is approximately the theoretical temperature calculated from the heats of reaction and the thermal capacities of the materials involved, and it might have been expected that in the shallow fuel bed the reactions involving the production of a considerable proportion of carbon dioxide would give rise to a temperature of over 1600°. However, in the deep bed producer the gasification of the coke by the air takes place at a considerable distance from the point at which the coal is being distilled, while in the shallow bed producer there is no sharp distinction between the gasification and distillation zones. Probably more heat is lost by radiation from the bottom of the grate in the shallow bed than in the deep bed; but on the other hand, in the deep bed producer a great deal more heat is lost by lateral conduction than in the shallow bed producer.

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[*] *Stahl und Eisen*, 1902.

The heat of the reactions taking place in the fuel bed may be represented by:—

C to CO_2	0·600 × 96600	= + 58500 K	per hour.
C to CO	2·400 × 29450	= + 68590	,,
Decomposition of moisture...........	0·067 × 39600	= 2660	
Distillation of coal		= X	
Loss by radiation		= Y	
Thermal capacity of the fuel		= Z	

It is only the amount of energy which is actually lost. A rough approximation of the value of X may be arrived at by assuming that as air is being drawn in through the grate bars there is no loss by convection, and that the loss is by radiation from the fire-bars and iron work of the grate, and from the partly glowing and partly black fuel between them. Allowing for 1 square metre of iron work radiating at 300°, and 0·3 square metre of fuel radiating at 750°, we obtain a value approximately equal to 20,000 K per hour. If we allow 25,000 K per hour for the total loss from the grate, we shall probably not be far wrong. As the upper part of the producer is surrounded by the down flues from the furnace, and by the recuperators, the loss from it will be small. Neglecting the thermal capacity of the fuel, the energy of the gas entering the furnace chamber will then be:

$$500{,}000 - 25{,}000 \text{ K} = +475{,}000 \text{ K per hour.}$$

It must be pointed out that many glass-makers imagine that there is an enormous advantage in producing gas in a central producer and "piping" it to the furnaces. Unless the furnaces are regenerative, and the gas as well as the air is preheated, there is a very considerable thermal disadvantage in the procedure, which is then only to be justified on the score of labour economy or saving in capital expenditure. In small installations it has very commonly been found that the centralised production of gas has proved anything but economic.*

The air required to gasify the fuel in the producer will contain:

Oxygen	1·766	Kilo-molecules.
Nitrogen	6·594	,, ,,

The composition of the gas entering the furnace chambers will be:

CO	2·400	Kilo-molecules.
H_2	1·267	,, ,,
C (as hydrocarbon)	0·850	,, ,,
O (combined)	0·150	,, ,,
CO_2	0·600	,, ,,
N_2	6·626	,, ,,

Furnaces of this type, unless under very careful control, usually work with a considerable excess of air, and 50 per cent. is not too much to allow for, particularly if smoking is to be avoided after firing up. The quantity of air required to burn the gas will be:

O_2	3·801	Kilo-molecules.
N_2	14·299	,, ,,

The composition of the waste gases, as they enter the down flues, will be:

CO_2	3·850	Kilo-molecules.
H_2O	1·267	,, ,,
O_2	1·267	,, ,,
N_2	20·294	,, ,,

We can now deal with the thermal changes taking place in the furnace. If the secondary air is recuperated to 800°, the energy brought into the furnace by the air will be:

$$18{\cdot}100 \times 5820 = +105{,}000 \text{ K approx.}$$

The total heat brought to the furnace chamber will be

$$475{,}000 + 105{,}000 = +580{,}000 \text{ K.}$$

It is not an easy matter to arrive at an estimate of the average flue temperature, for as the thermal capacities of the gases are very much smaller than the materials of which the furnace is built, the temperature of the gases, at their lowest temperature, will probably be below that of the flue walls, and, at their highest temperature, will be above that of the flue walls. The heat interchange between a pyrometer stem placed in a flue and the walls of the flue, by radiation, is probably more rapid than between the gas and the pyrometer by conduction and radiation. The fact is that we really do not know what we are measuring.

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* In an investigation of the thermal efficiency of a Gaillard evaporating plant carried out by the Ministry of Munitions it was found that the loss of energy between the fuel hoppers and the evaporators was 25 per cent. of the total energy of the fuel.

We can calculate the heat which will be conveyed away by the waste gases at 1200° and ~~1500°~~ 1300 as below:—

	Composition of gas, Kilo-mol.	Thermal capacities, K per Kilo-mol.		Total thermal capacity.	
		1200°.	1300°.	1200°.	1300°.
By CO_2	3·850	15550	17360	59900	66900
By H_2O	1·267	13870	15430	17600	19600
By N_2	21·566	9050	9890	195100	213300

Total at 1200°, 272600 K per hour.
Total at 1300°, 299800 K per hour.

Of this about 105,000 K is recuperated by the secondary air, and the balance is lost by radiation and conduction from the lower part of the furnace, or in the stack. Probably during the early part of the found, when all the pots have been filled with cold material, the flue-gas temperatures will fall below 1200°, and when the pots are nearly plain, and still stoppered, so that the glass is at 1300°, the flue-gas temperature will rise above 1300°, but under ordinary conditions it will be between 1200° and 1300°.

The average rate of consumption of energy in the furnace will lie between 280,000 K and 300,000 K per hour, and this energy will be used up in melting glass, or in balancing losses due to conduction and radiation. We will consider the amount of energy used for melting the glass, and also the losses, later.

If the gases pass to the stack at between 500° and 600° C., the heat which they will carry will be about 100,000 K to 125,000 K per hour. This would leave a balance of 70,000 K per hour for loss by radiation and conduction from the lower part of the furnace. It may be pointed out that on theoretical grounds it may be assumed that the heat lost in the flue gases in a singly-recuperative system is large, though the total efficiency may be fairly high.

The following may be taken as a rough estimate of the energy balance-sheet of the furnace:—

	K per hour.	Per cent.
Energy supplied to furnace	500,000	100
Energy lost from grate	25,000	5
Energy utilised in furnace chamber and lost by radiation and conduction from it	280,000 to 300,000	56 to 60
Energy lost by radiation from lower part of furnace	70,000	14
Energy carried to stack	100,000 to 125,000	20 to 25

IV.

When we come to consider the thermal data required to enable us to calculate the quantity of heat required to melt a glass of definite composition, we find that our knowledge of the subject is not very satisfactory. Only one set of determinations of the specific heats of a glass over a wide range of temperature can be found, and then the material is referred to merely as "soft glass." However, generally speaking, the "interval specific heats" of materials such as those from which glass is made increase with temperature in the approximate proportion,

$$S(0\text{—}1300^\circ\ \text{C.})/S(0\text{—}100^\circ\ \text{C.}) = 3/2.$$

If, therefore, we calculate the specific heat of our glass between 0° and 100° (Hovestadt, 196), we obtain the value:

$$\left.\begin{array}{ll} SiO_2 \ldots\ldots\ldots\ldots & 0{\cdot}6 \times \overset{0.1913}{\cancel{0{\cdot}1013}} \\ PbO \ldots\ldots\ldots\ldots & 0{\cdot}3 \times 0{\cdot}0512 \\ Na_2O \ldots\ldots\ldots & 0{\cdot}1 \times 0{\cdot}2674 \end{array}\right\} = 0{\cdot}156.$$

We can then obtain an approximation to the value over the wider range of temperature:

$$\left.\begin{array}{ll} SiO_2 \ldots\ldots\ldots\ldots\ldots & 0{\cdot}6 \times 0{\cdot}25 \\ PbO \ldots\ldots\ldots\ldots\ldots & 0{\cdot}3 \times 0{\cdot}07 \\ Na_2O \ldots\ldots\ldots\ldots & 0{\cdot}1 \times 0{\cdot}4 \end{array}\right\} = 0{\cdot}21.$$

The heat required to melt 1 kilogram of cullet, and to raise its temperature through 1300° will then be -272 K.

The batch corresponding to this glass would contain, for each kilo of glass made from it:

	Gram-molecule.		Gram-molecule.
SiO_2……………	10·00	Na_2O……………	1·61
PbO …………	1·36	CO_2 ……………	1·00
O_2 as PbO_2……	0·34	N_2O_5 ……………	0·61

In order to calculate the heat required to found the batch, we have to determine the values of the following factors:

(*a*) The sum of the specific heats of silica, lead oxide, and sodium oxide as glass $= -272$ K.

(*b*) The latent heat of fusion of silica,

$$SiO_2\ (\text{sand}) \longrightarrow SiO_2\ (\text{glass}).$$

(*c*) The heat of the reaction,

$$\text{i. } Na_2O\ (\text{solid}) + SiO_2\ (\text{sand}) = Na_2SiO_3\ (\text{glass}).$$
$$\text{ii. } Pb_2O\ (\text{solid}) + SiO_2\ (\text{sand}) = PbSiO_3\ (\text{glass}).$$

(*d*) The heat of the reaction,

$$\text{i. } Na_2CO_3\ (\text{solid}) = Na_2O\ (\text{solid}) + CO_2\ (\text{gas}).$$
$$\text{ii. } 4NaNO_3\ (\text{solid}) = 2Na_2O\ (\text{solid}) + 5O_2\ (\text{gas}) + 2N_2\ (\text{gas}).$$
$$\text{iii. } 2PbO_2\ (\text{solid}) = 2PbO\ (\text{solid}) + O_2\ (\text{gas}).$$

(*e*) The thermal capacities of the gases which are liberated at about and below 1000° C.

(*a*) Taking each of these in turn, we may remark that the value of the specific heat has already been considered.

(*b*) The value of the latent heat of silica is a matter of some uncertainty. Cunningham [*] and Vogt [†] give estimates of 0·1 K to 0·13 K per gram, or between 6 K and 9 K per gram-molecule, which, though probably near the mark, are based upon very questionable data. Washburn [‡] has calculated the latent heat of *cristobalite* from the melting point of *cristobalite* and the melting point and composition of the eutectic, Al_2O_3,SiO_2. He assumes, and probably rightly, that the solute is the simple silicate, Al_2O_3,SiO_2, which separates as *sillimanite* at that temperature. He obtains the value 6·8 K for the value of the mol. latent heat of *cristobalite*.

Tschernobaeff,[§] following the method of Le Chatelier,[||] using a calorimetric bomb, determined the following heat changes, from which the heat of the reaction,

Silica cryst. ⟶ Silica as glass,

can be deduced. They are:

$= Na_2SiO_3$(glass)

SiO_2 sand $+ Na_2CO_3 + CO_2 - 30{\cdot}4$ K.

$10SiO_2$ sand $+ Na_2CO_3 = (9SiO_2,Na_2SiO_3)$ glass $+ CO_2 - 96$ K.

If the difference, $-(96\ K - 30{\cdot}4\ K)$, is the latent heat of liquefaction of the nine additional molecules of silica, we obtain the value $-7{\cdot}3$ K, which differs only slightly from the value arrived at by Washburn. We may take -7 K as the approximate value.

Tschernobaeff did not pay attention to this pair of reactions, but tried to arrive at the latent heat of silica by measuring the heat of the reaction, $Na_2CO_3 + 10SiO_2$, using first sand and then vitreous silica. He obtained variable results, the greatest difference corresponding to $-2{\cdot}3$ K, and the mean to $-0{\cdot}9$ K for the molecular latent heat. It seems probable that the vitreous silica used was partly devitrified.

The value of factor (*c*) i. (p. 219) is therefore

$$-\{10{\cdot}00 - (1{\cdot}36 + 1{\cdot}61)\}7\ K = -\underline{49\ K.}$$

(*c*) From the experiments of Tschernobaeff and others, we obtain the relationships:

Na_2CO_3 (solid) $+ SiO_2$ (sand) $= Na_2SiO_3$ (glass) $+ CO_2 - 30{\cdot}4$ K.
Na_2CO_3 (solid) $= CO_2 + Na_2O - 76{\cdot}9$ K.
Na_2O (solid) $+ SiO_2$ (sand) $= Na_2SiO_3$ (glass) $+ 46{\cdot}5$ K.

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[*] *Proc. Dublin Roy. Soc.*, 1900, **9**, 414. [†] *Zeitsch. Elektrochem.*, 1903, **9**, 852.
[‡] *J. Amer. Cer. Soc.*, 1919, 2, 1007. [§] *Rev. de Métallurgie*, 1905.
[||] *Compt. rend.*, 1895, **120**, 625.

The value of factor (*c*) i. is therefore

$$(1{\cdot}61 \times 46{\cdot}5)\ \text{K} = +74{\cdot}5\ \text{K}.$$

We have no positive information as to the thermochemistry of the reaction

$$\text{PbO (solid)} + \text{SiO}_2\ \text{(sand)} = \text{PbSiO}_3\ \text{(glass)}.$$

The heats of formation of lead compounds do not, however, differ greatly from those of calcium compounds, having generally a slightly lower value. From the experiments of Le Chatelier * and Tschernobaeff,† we have the following relationships:

$\text{CaO} + \text{SiO}_2\ \text{(sand)} = \text{CaSiO}_3\ \text{(glass)} + 16\ \text{K}.$
$\text{SiO}_2\ \text{(sand)} = \text{SiO}_2\ \text{(glass)} - 7\ \text{K}.$
$\text{CaO} + \text{SiO}_2\ \text{(glass)} = \text{CaSiO}_3\ \text{(glass)} + 23\ \text{K}.$

If we take the heat of reaction between lead oxide and silica to be two-thirds that of the reaction between lime and silica, we may write:

$$\text{PbO} + \text{SiO}_2\ \text{(sand)} = \text{PbSiO}_3\ \text{glass} + (16 - 7)\ \text{K}.$$

This is a guess; but a large error here is not of very material importance, for the value of the factor (*c*) ii. is only

$$(1{\cdot}36 \times 9)\ \text{K} = +12{\cdot}2\ \text{K}.$$

(*d*) The values of these factors are:

$$\begin{array}{rlcr} \text{i.} & (-\,76{\cdot}9 \times 1{\cdot}00)\ \text{K} & = & -\,76{\cdot}9\ \text{K} \\ \text{ii.} & (-\,10{\cdot}0 \times 0{\cdot}61)\ \text{K} & = & -\,6{\cdot}1\ \text{K} \\ \text{iii.} & (-\,13{\cdot}0 \times 0{\cdot}34)\ \text{K} & = & -\,4{\cdot}4\ \text{K} \\ \hline & \text{Total} & = & -\,87{\cdot}4\ \text{K} \end{array}$$

(*e*) The thermal capacities of the gases which begin to be evolved at a low temperature, and which are practically completely drawn off between 1000°, may be calculated from Holborn and Henning's results, taking their mean temperature as 800°:

$$\begin{array}{lcr} \text{CO}_2 :\!-\!(1{\cdot}00 \times 9{\cdot}18)\ \text{K} & = & -\,9{\cdot}18\ \text{K} \\ \text{N}_{21}\text{O}_2 :\!-\!(0{\cdot}61 \times 3\tfrac{1}{2} \times 5{\cdot}82)\ \text{K} & = & -\,12{\cdot}42\ \text{K} \\ \hline \text{Total} & = & -\,21{\cdot}6\ \text{K} \end{array}$$

The total heat required to produce 1 kilogram of glass from the batch is thus the sum of the factors:

$$\left.\begin{array}{lr} a \ldots\ldots\ldots\ldots\ldots\ldots & -\,272{\cdot}0\ \text{K} \\ b \ldots\ldots\ldots\ldots\ldots\ldots & -\,49{\cdot}0\ \text{K} \\ c\ \text{i.} \ldots\ldots\ldots\ldots\ldots & +\,74{\cdot}5\ \text{K} \\ \quad\text{ii.} \ldots\ldots\ldots\ldots\ldots & +\,12{\cdot}2\ \text{K} \\ d \ldots\ldots\ldots\ldots\ldots\ldots & -\,87{\cdot}4\ \text{K} \\ e \ldots\ldots\ldots\ldots\ldots\ldots & -\,21{\cdot}6\ \text{K} \end{array}\right\} = -\,343\ \text{K}$$

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* *Loc. cit.*

† *Loc. cit.*, and *Compt. rend.*, 1910, **154**, 206.

The heat required to produce glass from the usual mixture of half batch, half cullet, is, per kilogram of glass, $-\frac{1}{2}(343+274)\ \mathrm{K} = -300\ \mathrm{K}$ approximately.

If each pot is charged with 600 kilos. (13 cwt.) of glass, the heat required to found the metal in the eight pots will be

$$-(8\times 600\times 300)\ \mathrm{K} = -1{,}440{,}000\ \mathrm{K}.$$

The average rate of absorption of heat by the glass, if the metal takes twelve hours to found and plain, will be $-120{,}000$ K per hour; but this figure has very little real significance, for it is probable that the rate of flow of heat into the pots is very much more rapid during the first few hours than towards the end of the operation, when the temperature is merely being raised to the point at which the viscosity of the glass is low enough to allow the *seeds* to rise rapidly, and the metal to plain.

It would not be difficult to follow the chemical and physical changes taking place in a glass pot while the metal is founding and plaining, but the experiments would take time and would be rather expensive to carry out. Little information is to be gained from the temperature of the flue gases during the found, on account of their relatively small thermal capacity compared with those of the material of which the furnace is built.

An attempt was made to arrive at an estimate of the amount of heat required to found the metal from the following considerations. When the metal is plain and the stopper of the pot is taken down, the metal cools off rapidly to a certain temperature, which is maintained so long as the temperature of the furnace is kept constant. If the furnace is "dropped," the pots cool off more rapidly, and to a lower temperature, and in some furnaces this must be done before the metal can be worked. If the pot loses heat only by radiation through the mouth, the maximum rate of loss of heat can be calculated on the assumption that the pot is a "constant temperature enclosure," and that the walls of it radiate in accordance with the law for "black bodies." Neither of these assumptions are entirely justified. The total heat loss will then be given by the equation,

$$R = EAr(T^4 - T_1^4)\times 3600\ \mathrm{K\ per\ hour},$$

where E is a constant dependent on the nature of the material, and on the temperature, which for a "black body" is unity; A is the area of the pot mouth in sq. cm.; r is the constant of radiation, the value of which may be taken as $1{\cdot}3\times 10^{-15}$ K per second per sq. cm. of the area of the pot mouths; and T and T_1 are the temperatures of the inside of the pots and of surrounding objects,

T_1 being neglected in calculations involving high temperatures. We obtain the following values for R:

Temperature inside pots.	R in K per hour.
1100°	72,500
1200°	96,100
1300°	123,200

The working conditions which would found the glass in twelve hours would not maintain the temperature at 1200° C. when the stoppers were fully removed. There must be another cause of loss of heat from the pots, and it can only be suggested that it is due to convection currents.

If a piece of smoking coal or a piece of ammonium chloride is placed on the lip of a pot, the smoke or fume is drawn into the pot. If the pot is nearly full, it travels along the surface of the glass, but if the pot is only partly filled with glass, it passes sharply over the lip and down into the pot. If the smoking material is held on a paddle about the middle of the pot mouth, no particular effect is observed; but if it is held under the arch of the pot mouth, about 2 cm. from the underneath of the arch, one obtains evidence of a current of air blowing out of the pot. Of course, the coal or ammonium chloride generates gas itself, and the experiment with the material on the lip of the pot is the most significant one.

That a current of air does blow out under the arch is proved by presenting the end of a piece of copper tube, connected with a sensitive, inclined water gauge, at the mouth of the pot just below the arch, and observing the Pitot effect. An actual pressure of 0·02 cm. water gauge was observed, but this fact alone cannot be made use of in estimating the magnitude of the effect.

The front of a pot is always considerably colder than any other part of it, and particularly than the back and top, so that when the pot is only partly filled it is easy to account for the convection currents. The exact cause of the formation of the convection currents about a full pot is not quite so clear, for it is not entirely a question of temperature, but of the manner in which the air receives the heat from the hot surfaces of the glass and of the pot. The investigation of the convection currents in a glass pot would be interesting with a view to determining their influence in the formation of surface cords.

Technical literature contains very little information with regard to the experimental determination of heat losses from furnaces, but several authors describe experiments in which they have attempted to determine such losses by placing metal vessels containing water against the walls of flues, etc., and measuring the rate of rise of temperature of the water. Whatever the results obtained by this method may refer to, they have no connection with the heat losses when the surfaces are simply in contact with the air.

It has for long been known that heat transference from a solid surface is due to two distinct phenomena. Part of the heat is lost by radiation, in accordance with the law already stated. Part is lost by conduction through a thin, immobile layer of air on the surface of the solid. The rate of loss of heat is dependent upon the temperature of the surface, the constant E, which for fire-brick at fairly low temperatures is about 0·75, the thickness of the air layer, which appears to be 0·45 cm., the conductivity of air, and the area of the surface. The form of the surface, and its position, must also be taken into consideration; but according to Langmuir,* who investigated the problem mathematically and experimentally, the cases of a flat surface placed horizontally and exposed from above, or placed vertically, is fairly simple.

The crown of the furnace described in this paper may be considered to be a flat surface of 122,000 sq. cm. area. Its temperature was found to be between 250° and 300° by the simple process of dropping on to it powdered materials of known melting point, and observing their behaviour. Without going into the details of Langmuir's calculations, it may be stated that the following values for the rate of loss of heat can be obtained from them:—

Temperature of surface.	Loss of heat.
250° C.	45,100 K per hour.
300° C.	63,000 K per hour.

If we take the temperature inside the crown of the furnace to be 1350° C. when it is melting glass (the pots are at 1300° C. when they are taken down), the thickness of the crown to be 30 cm., and the conductivity of the material, which is fireclay, to be 40×10^{-7} K per cm. per second, we obtain the following values for the heat supplied to the surface:—

Temperature of surface.	Loss of heat.
250° C.	64,500 K per hour.
300° C.	61,000 K ,,

If the actual temperature were 290°, the two sets of results would agree exactly, but the data are only approximate, and it is rather remarkable that they agree at all. However, while in the absence of data it is not worth while carrying speculations further, it may be pointed out that it should not be difficult, on the basis of proper experiments, to obtain a fairly accurate estimate of the heat losses from various parts of a furnace to the outside. As the area of the crown of the furnace is little over one-third of the total area of that part of the furnace which is above the working floor, and as heat is lost by conduction through the siege, though loss in this direction is avoided to a considerable extent owing to the position of the flues, it does not seem unlikely that the total loss from the furnace chamber itself is 160,000 to 180,000 K per hour, which is considerably greater than the amount of heat utilised in melting the glass during the period of founding.

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* *Trans. Amer. Electrochem. Soc.*, 1913, 23, 299.

Beacon Hall, Priory Gardens,
Highgate, London, N.6. [*June*, 1920.]

Discussion of the above paper is invited.

XVIII.—*The Development of Optical Glass during the War.*

By C. J. Peddle, D.Sc.

(Introductory statement at London Meeting, May 19th, 1920, to series of papers entitled "The Development of Various Types of Glasses.")

During the three years since I was last able to contribute a paper to the Society, it has been my privilege to assist in the development of the optical glass industry in this country, and so successful has that development been that we are no longer dependent upon foreign sources of supply for our optical glass, but are quite self-supporting. In pre-war days some 90 per cent. of our optical glass supplies were imported, 60 per cent. from Germany alone, so that the outbreak of war found us in a very parlous condition. Fortunately, one firm had kept the optical glass trade flag flying in this country for many years, and all honour is due to Messrs. Chance Bros., of Birmingham, for persevering in so difficult a manufacture in most adverse circumstances. The fact that when war broke out an optical glass works was in existence, staffed by experts and capable of expansion, must not be lost sight of, and this country owes a very large debt to Messrs. Chance Bros., who for more than two years alone bore the brunt of production.

Early in 1916, the great advances in aerial photography and the large increase in the *personnel* of our fighting forces caused the demand for optical glass to be multiplied many times, and the

Government began to look for other sources of supply. Accordingly, Messrs. Wood Bros. Glass Co., Ltd., of Barnsley, were approached on the matter, and it was decided to attempt manufacture at their Derby works. It is with great diffidence that I speak of the work accomplished there, but I am told it will be of interest, and so I will make some brief reference to it. Begun in June, 1916, within three years some seventy different types of glass have been developed. These comprise practically the whole of the important pre-war glasses, and in addition several new types hitherto unavailable. The work entailed has been enormous, for no one connected with it had any previous knowledge of optical glass manufacture. The difficulties were enhanced by the fact that production had to be hurried, that the glasses had all to be worked out, and that methods of production had to be investigated. Perhaps I may be pardoned a feeling of pride when I think that, in face of unparalleled difficulties, we have accomplished in three short years practically as much as it took our late enemies across the Rhine thirty years to do, and that we are now purveyors of glass to the whole world. The quality of the glass now being produced is quite up to the pre-war standard; in fact, in certain particulars the pre-war quality is surpassed. I do not say this upon my own initiative, but on account of reports we have received from prominent opticians, both in this country and abroad.

My own share in this achievement has been largely concerned with the scientific side, and my papers deal with some of the earlier work. As will be recognised, during my investigations a considerable amount of knowledge has accumulated, and this knowledge is probably of interest to all concerned with glass manufacture, and its kindred problems. Mr. Frank Wood, I am pleased to say, shares my opinion that this knowledge should be published, and it is with his permission and on his advice that I make it known. My scheme for publication is a very comprehensive one, and I am afraid it will be some considerable time before it reaches a conclusion. The present series of papers deals with the alkali-lime-silica glasses. At some future date, if members so desire it, I propose to deal with the alkali-lead-silica glasses, and later with the barium glasses and other types. I recognise the fact that I am setting myself a somewhat formidable task, but my reward will be in the good it may bring to the industry.

In the manufacture of optical glass many points have to be taken into account. The manufacturing optician demands that his glass shall have certain refractive indices, be free from cords or veins, have practically no colour even in thick pieces, and be practically free from bubble. In addition, he expects the glass to be durable and free from strain. Thus the glass manufacturer has to work out particular batches for each type of glass and to investigate conditions of melting, stirring, cooling, moulding, and annealing. It will be seen that many difficulties stand in the way of the production of first-rate optical glass. Perhaps the greatest of these difficulties is the pot in which the glass is melted. Very early in our work we recognised that the pots at present available are by no means ideal, and we began work to try to improve the glass pot for our purpose. We welcomed the news when we heard it that research was being carried out at the National Physical Laboratory, under the auspices of the Government, to provide the optical glass industry with suitable refractory materials. It gave us some feeling of relief that valuable time we had intended to devote to the refractory materials side could now be given to other pressing matters. I need scarcely say how keen has been our disappointment in the optical glass industry that, up to the present, no practical results have shown themselves from the National Physical Laboratory research. We feel, in the industry that, having got so far under present conditions we could go much further with better refractory materials; in fact, I am bold enough to say that difficulties with glass pots, and those alone, are all that stand between us and glass of a quality hitherto undreamed of. In addition, given such refractory materials, the industry could be made to pay its way, and the optician be provided with a cheaper and better glass. When it is remembered that 80 per cent. of even a successful melt is sheer waste owing to the evils of pot attack, our wishes will be appreciated for a better refractory material, and our disappointment that, like the will-o'-the-wisp, it still eludes us. We all recognise how difficult research on refractory materials is, how patient one has to be in waiting for results, and how heart-breaking those results so often are; and I trust that the work at the National Physical Laboratory to provide a special refractory material for the optical glass industry will continue, possibly under the auspices of the Glass Research Association, and be brought to a successful conclusion. The blessings of a whole industry await them.

Having outlined some of our difficulties, I must now show how, in some measure, we endeavoured to overcome them. It is obvious that little or no progress could be made in manufacture unless a considerable amount of research were carried out dealing with each point mentioned. Accordingly, concurrently with an attempt to make some optical glass, I began systematic researches upon most of the points I have outlined. We were anxious, of course, to begin manufacture as soon as we could, and in the early days we turned naturally to that fount of glass knowledge, Sir Herbert Jackson, for batches. We were not disappointed, for Sir Herbert was able to suggest batches which he had worked out for seven different glasses, and the first melts at Derby were made using his formulæ. Unfortunately, these formulæ did not yield glasses of the optical constants so urgently required, and that brings me to a further problem we had to face. When the Schott firm developed their famous glasses, they did so from arbitrary formulæ, and gave the indices to the optician. He in turn worked out his lens combinations and made his machinery to suit these glasses. Our problem was the reverse of this, and therefore so much the harder. The optician said, in effect, "We have made our calculations and our tools to suit a particular glass of a certain index, and so you must make glass correct to that index." It was thus early evident that batch formulæ worked out from analyses of existing types of glass, which gave accurate results on small meltings, would not do so on large scale meltings. The reason for this I show later in my papers. I decided therefore to abandon this method of analysis of existing types, and of devising formulæ from the analyses. In the first place, as I have pointed out, batches worked out in this way, even allowing for volatilisation, do not yield glasses of the required nature, and, secondly, it is the crude method of the copyist, and so can lead to no production of new types, and after all it is only upon the production of new types and the improvement of old ones that any advance in optical instruments can take place. Instead of the method of analysis, I decided to use a study of the influence of glass-making oxides upon one another. It has been a most successful method of attack upon a difficult problem, and the whole of the glasses now being produced at Derby have been worked out in this way. As far as possible, the study has been supplemented by analysis, but many glasses in pre-war use have been worked out without any of the original glass being available.

[Then followed a general résumé of the five papers.]

Discussion on Dr. Peddle's Papers.

Mr. S. N. Jenkinson thanked Dr. Peddle for his paper, which, he thought, was quite human and understandable, as well as scientific. It had been presented in a way which made it capable of being readily understood by all. He thought that thanks were due to Mr. Frank Wood, of Barnsley, for allowing the knowledge gained in his works to be placed before the members of the society for their benefit.

It was very interesting to hear that we were now the world's suppliers of optical glass. He had recently heard of a firm who had changed over their order for such glass from Germany to the United Kingdom. Dr. Peddle had shown the value that science could be to the optical glass industry, a very important point. He did not see why science could not be applied to every branch of the glass industry, so that we could become the world's suppliers. The extraordinary results achieved by Dr. Peddle were a step in that direction and a great help to the country.

Dr. W. E. S. Turner also paid a tribute to the work of Dr. Peddle, who was an old student of his and now a close friend. He thus had an opportunity of knowing how extraordinarily enthusiastic had been Dr. Peddle's work. All too much of this world's affairs were carried on on the basis of opinions only. Science was not free from this defect. People still preferred often to talk than to make experiment. Dr. Peddle was a man who preferred to work.

The five papers presented would make the production of their Journal dearer, but there was no reason to regret that. They indicated to the industry that there was a school of young thinkers and workers bent on the development of a British glass industry.

When a scientific man found no material and no data available for his own purpose it was not entirely a matter of regret. It gave him, at any rate, the opportunity of starting from the beginning without any theories to hamper him. Further, the present five papers presented were the forerunners of quite a number of others for which data were available, and he could assure Dr. Peddle that whether manufacturers expressed a desire or not, the Editor would not cease to press for the remaining papers. The difficulty had been to persuade Dr. Peddle to cease experiment temporarily and write up his results.

Dr. Turner went on to pay a tribute to Mr. Frank Wood. He had previously commended the example of the American workers in the new field of the optical glass production for the full and frank manner in which they had discussed their results. Some firms, he said, accumulated scientific data, but refused to allow them to be discussed. Firms who employed scientific assistance stood to gain most by encouraging their technical staff to enter into scientific discussions, giving as well as taking. It was therefore a matter of great satisfaction that Messrs. Wood Bros. should permit the publication of Dr. Peddle's papers.

Dr. Peddle had not in his address dealt in detail with the data given in the papers, nor had he wearied them with figures. There were, however, one or two general principles to which he would like to refer. In the first place, the results which had been published embodied data obtained from an enormous number of meltings on a small scale. Many manufacturers questioned the utility of experiments on glass made in a "thimble." He would, therefore, ask Dr. Peddle his frank opinion as to the results of meltings on, say, the half-a-pound scale, since he also had had the opportunity of making side by side with these melts others on the 10 to 20 cwt. scale. The latter had obviously been a great success, and manufacturers would like it emphasised that such success had been based on the results of the very small scale melts.

Dr. Turner went on to refer to the question of annealing, a matter which made considerable difference to the value of any property measured—for example, to the refractive index—and density; the latter was particularly sensitive. A badly annealed glass behaved like most metals. Thus, the density of copper does not increase when hammered or subjected to pressure. Since there was no precise mention of it in Dr. Peddle's papers, he would like information as to how the specimens of glass had been annealed.

The next point was that the data were arranged in such a way that in the curves given the composition employed was the initial batch composition and not that of the finished product. It was a question whether and how far this method was justifiable and how far the curve of the relation between property and composition held good. He, himself, had hitherto preferred to plot the actual analytical composition, rather than surmise that the glass contained the same oxides from the same proportions as in the batch.

Among other points, Dr. Turner referred to Dr. Peddle's conclusion with regard to mixed soda and potash glasses. Dr. Peddle's results harmonised with his own results already published for lead containing glasses, that a mixture of soda and potash produced a much better glass than one with potash or soda alone. The durability of a glass with both soda and potash was much enhanced. Further, a mixture of soda and potash in equivalent proportions gave glass which was exceedingly good for lamp-working.

In conclusion, Dr. Turner referred to methods of testing durability, and to the method Dr. Peddle had used in the extrapolation of values.

Dr. W. Rosenhain said that he would like to associate himself with the tribute that had been paid to Dr. Peddle's labours. He could quite well conceive how vast had been the work, since he himself, in perhaps far less favourable circumstances, had had years ago to carry out work of a somewhat similar character.

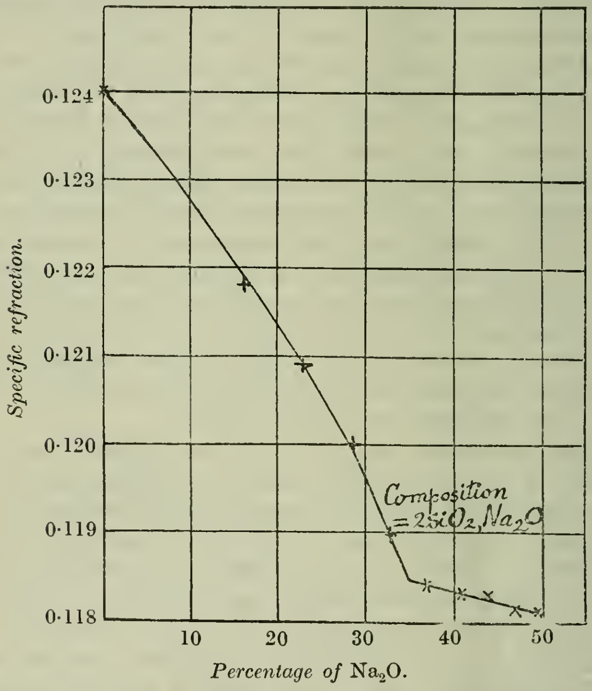
There were some of Dr. Peddle's remarks, however, to which he should like to make a reply. He certainly thought that the remarks in regard to the researches on refractory materials being carried out at the National Physical Laboratory were rather unfair. He (Dr. Rosenhain) must take exception to the view that no results had yet been presented. He emphasised the fact that at least one definite law had been established governing the nature and mechanism of the solution of glass in open pots. The fault he had to find in regard to Dr. Peddle's melts was that the latter had melted all his glasses irrespective of their composition at about the same temperature. This was unfair to the glasses and also unfair to the pots in which they were melted. There was no doubt that the more fusible glasses would thus become discoloured owing to the material dissolved by the use of an excessive temperature. Speaking of glass pots, he did not see why an ideal pot which would be iron-free could not be produced by using either a pure china clay or a purified clay such as was produced by the electro-osmosis process. If such a pot could be tried, he thought it would be successful, especially for optical glass manufacture. The best clays in any case would have to be used, and during the melting process regard would have to be had to the critical temperature of pot attack. He did admit that the production of the ideal pot was still before them and that very much more work might still be needed. He did consider, however, that to say that the National Physical Laboratory results had not led to any serviceable result was not true in view of the law which had been established, and it was certainly the business of workers in the industry itself to see that this law was made use of and applied.

Dr. Rosenhain went on to refer to the peculiar way in which Dr. Peddle had presented his data. He could not help wishing that Dr. Peddle had adopted the equilateral triangle diagram for the purpose of plotting his results. This method was readily comprehended. There would be no difficulty in replotting the data on the equilateral triangle method, and the results would be quite instructive. As an alternative, the method which Dr. Turner had employed in his investigations, particularly in the study of the tri-silicate glasses, was, in his opinion, preferable to that in which the sum total of the bases varied instead of being a fixed quantity.

In reference also to Dr. Peddle's remarks about the difference between results of small and large scale melts being due largely to volatilisation of alkali, he, Dr. Rosenhain, thought there was some misapprehension about the subject of alkali volatilisation. From his own experience of the examination of flue dusts, the amount of alkali volatilisation was small and actually the bulk of flue dust was made up of silica, which was a rather striking result to find.

He would also like to refer to Dr. Peddle's attempt to connect the amount of attack on the glass pot by the colour of the glass. In his own opinion it would not be fair to do this, since the influence of alumina on the optical properties had to be always borne in mind.

The physical and chemical properties studied by Dr. Peddle did constitute a mass of very valuable data of a kind that had been badly wanted in the glass industry. He hoped it would be possible to carry them a step further. Some research work was shortly to be begun by the Glass Research Association dealing with such questions as viscosity. It would be extremely useful if this research could be extended to such synthetic glasses as Dr. Peddle had produced, and his co-operation would be valuable.



Mr. VAUGHAN H. STOTT said that when plotting physical constants empirically against the composition of a mixture, it was convenient so to choose the variables that a simple physical conception, approximating to the phenomenon involved, was represented by a very simple curve. By so doing, the nature of the relation considered was readily grasped. Thus, in Dr. Peddle's papers, it was more convenient to plot against the percentage composition by mass, the specific volume, rather than the density, since the former method gave a straight line in the simple physical case of two substances mixing without change of volume. The divergence of the actual phenomenon from this simple conception was immediately seen in the curvature of the experimental line.

In the case of the relation of refractive index to composition, it was useful to plot the "specific refraction" against the composition by mass, as there were theoretical grounds for the belief that the result would be nearly a straight line.

In connection with Dr. Turner's paper on coefficients of expansion, it would be convenient to plot them against the compositions expressed as percentages by volume, instead of by mass, as a straight line would then be obtained if the constituents mixed without volume change at all temperatures. In the two latter cases, the suggested choice of variables was only put forward as an addition to the existing choice, in order to aid in the comprehension of the results, since the method involved a knowledge of physical constants other than those of which the values were under consideration.

He had, for the sake of interest, plotted the specific refraction of the sodium silicates from Dr. Peddle's figures and had obtained the curve shown.

It would be seen that it afforded evidence of the existence of a compound, $2SiO_2,Na_2O$, a fact not obvious from a consideration of refractive index and density curves considered separately.

Mr. E. A. Coad-Pryor said that not long ago, in discussing the question of optical glass with a French scientific worker, the latter had remarked that the glass recently received from this country was very considerably in advance of any German pre-war glass.

Referring to devitrification, he referred to the methods employed by Dr. Peddle in studying the subject, and pointed out that every glass would have a temperature at which the rate of devitrification was a maximum.

Mr. W. E. Oakden corroborated Dr. Rosenhain's remarks on the volatilisation of silica by referring to the loss in weight from quartz fibres on rise of temperature, a fact which could be detected by means of the micro-balance.

Mr. W. L. Baillie welcomed the new investigations. It had long been known that the work of Schott and Winkelmann needed revision. He believed it was true that the compositions given by these workers in their tables of physical properties related to the batch. If there were no loss of alkali or of silica the results would be as stated. After referring to the colours mentioned in Table II. of Dr. Peddle's first paper, Mr. Baillie went on to speak of durability and the dimming test. Referring to the filming test, he spoke of the attack of dust on the glass. In this connection he would like more information about Dr. Peddle's exposure tests. Were the specimens acted on by the ordinary dust-containing air of a room or were any precautions taken in view of the specific effect of dust?

Mr. R. L. Frink said he both agreed and disagreed with Dr. Rosenhain and Mr. Coad-Pryor as regards the volatilisation of silica. He had in one instance made the subject a matter of quite a thorough investigation and had found that in the tank furnace which was charged by means of a dog house, thereby reducing to the minimum the entrainment of batch materials, a moderately oxidising fire was maintained and when the gas was substantially dry or did not carry an excess moisture or steam, the deposit which was taken from the checker work, neck and rider arches, was composed mainly of sodium carbonate. The amount of soda was, as far as he could recollect, something over 80 per cent. The same furnace was then re-set, the top checkers being of new brick, this being accomplished during the Saturday and Sunday shut down, and the furnace worked with very heavy smoky and reducing flame for a considerable period (two or three weeks) and the gas contained a considerable proportion of water vapour. In this event, the material which was taken from the top of the checkers consisted of a considerable proportion of silica and its colour was a dark amber. The silica, he believed, amounted to between 50 per cent. and 55 per cent., and he never recalled having taken materials from a furnace charged by means of a dog house where the silica was in excess of 50 per cent. He was, therefore, of the opinion that Dr. Rosenhain's assumption of the excessive volatilisation of silica was perhaps governed to some extent by the method by which the batch materials were charged, and the degree of fineness of the sand; or, in other words, the amount of entrained sand that occurred in the exit gases. To his mind, it was quite conclusive, however, that there was a much greater volatilisation of soda than of silica unless a great deal of moisture and a strongly reducing flame were brought into contact with the batch materials.

Dr. Peddle, in reply, said in the first place he would express his thanks for the enthusiastic manner in which his papers had been received. He could not help but feel overwhelmed by all the kind things that had been said, and he was gratified that such a useful discussion had been aroused. Before dealing with the various points raised during the discussion, he would like to make a few general remarks. It must be remembered that the work outlined was carried out in the early days of development, when results were desired in a hurry and thus some of the properties had only been investigated in a somewhat cursory manner, and would bear further investigation. In travelling down the stream of research there were many captivating backwaters that cried out for exploration, but one had to keep the main end in view and not be tempted away by side issues, when time was a factor of such extreme importance. He would direct attention to the fact that the results did not pretend to be absolute values, because it was assumed in every glass that the batch composition represented the final glass composition. Some attempt had been made to carry out analyses of the glasses, but the work was long and arduous, and to wait until it was finished would mean postponing the papers, possibly for all time. It must also be remembered that precise glass analysis was one of the most difficult of analytical operations, and only by taking the mean of many analyses of the same glass could one be reasonably certain of the correctness of results. Sufficient work had been done on analysis, however, to prove that the general conclusions to be drawn were the same whether batch compositions or actual glass compositions were used in the interpretation of the results. Therefore to make the work immediately available for glass technologists he determined to publish it, giving the results in terms of batch compositions.

Turning now to the questions that had been asked, it would be found that some of them had been dealt with in the papers printed. The rest he would try to deal with in order.

Dr. Turner, to whom his special thanks were due, asked for his candid opinion as to the value of small meltings in the light of later commercial practice, and he would answer candidly that he had found them of the utmost value. In the first place they did indicate in which direction a property tended. To take a simple example, the addition of lime tended to increase the refractive index, and this could be shown by the results of small melts. Then they were of great use in comparing various properties of two or more glasses of similar type. Again much information was to be gathered as to the melting properties, weathering properties, and devitrification tendencies of a glass by small scale melting and subsequent experiment. Of course, caution had to be used in translating results obtained in small scale meltings into the large works scale, but experience soon taught one what pitfalls to look for and avoid. The second point raised by Dr. Turner, as to the state of annealing of the pieces of glass, was a very important one. One found in practice that the better annealed a glass was the higher were its density value and its refractive index. Thus a proof taken from an optical glass melt, if allowed to cool at the end of an iron, would have a certain refractive index. If the proof were allowed to pass down an ordinary bottle lehr, its index would be higher. If it were allowed to cool slowly in a first class lehr over, say, twenty-four hours, its refractive index would be higher still. Finally, if it were raised to just short of its deformation point and then allowed to cool slowly over a fortnight or more (that is, undergo the optical process of fine annealing) its index would be higher than that found after the twenty-four hours' process and would probably have reached a maximum. The amount of change of refractive index with state of annealing varied with the type of glass. It was greatest in such glasses as the Dense Barium Crowns and least with the Dense Flint glasses. In dealing with the glasses from his small melts it was impracticable to subject them to the long fine annealing process. Accordingly, the melts were allowed to cool slowly down over twenty-four hours in the furnace, the furnace being filled and covered by a heat-insulating material such as asbestos. It was found that the small pieces so obtained had a good degree of annealing, quite equal to much of the optical glass on the market.

He was very interested to learn from Dr. Turner of the results obtained at Sheffield with mixed soda and potash in the manufacture of glasses for tubing and with lead crystal glass for table ware, and that the mixed glasses were less soluble in water than either the soda or potash glass alone. Dr. Travers had also informed him that he found this state of affairs with table-ware. In passing, he would also point out that certain of the glasses studied by Capt. J. R. Clarke and Dr. Turner* are the same as some of those studied by himself, and the refractive index for the D line and the total dispersion were practically identical with those he obtained, being slightly greater. This was to be expected, as he believed their meltings were on a somewhat larger scale than his own. The one discrepancy was the dispersion value for the $Na_2O,3SiO_2$ glass.

He would also thank Dr. Rosenhain for his remarks, and would say at once that no one appreciated more than himself the work on refractory materials carried out at the National Physical Laboratory and it was with no sense of recrimination that he registered the disappointment of the industry that no practical results had yet appeared *from the point of view of optical glass manufacture.* The results so ably expounded by Dr. Rosenhain at last year's London meeting were of value as far as they went, but he failed to see how they could be applied with much advantage in optical glass melting, which only lasted a few days, and was carried out in closed pots. Many possibilities were put forward by Dr.

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* "The Optical Properties of some Lime-soda Glasses," this vol. Trans., p. 111.

Rosenhain, but the glass manufacturer could not be expected to spend thousands of pounds upon mere possibilities—what he required were certainties. What was desired from the research worker was a definite statement, saying, "Here is a refractory to which if you add grog in a certain way and mix it in a certain way, etc., it will make a glass pot which will satisfy your requirements or part of your requirements. *I know it will, because I have tried it.*" The whole crux of the matter lay in the last sentence. Research in refractory materials before presentation should have been carried through to a trial on a works scale. Then and then only could the manufacturer be truly satisfied.

Dr. Rosenhain had stated that he could have wished that more notice had been taken of the National Physical Laboratory work in some of the meltings carried out during his (Dr. Peddle's) research. That, of course, was impossible, as these meltings were done more than twelve months before Dr. Rosenhain's paper appeared. Apropos of this, he pointed out that his glasses had been melted irrespective of their composition and fusibility at about the same temperature, which was unfair both to the glasses and equally unfair to the pots. He was glad Dr. Rosenhain had raised this point, because when he began the work it caused him much searching of mind and long thought. Indeed, some of his preliminary meltings were done varying the time and temperature, but the fact that this introduced two more variables, and the fact also that he wished to be purposely unfair to the pots in order to gain as much information as possible regarding pot attack in certain circumstances, caused him to decide on the method employed.

He was particularly interested in Dr. Rosenhain's remarks that there was a possibility of an ideal pot being produced out of either pure china clay or of purified clay as produced by electro-osmosis, particularly for the optical glass industry and that work had been done at the National Physical Laboratory on the matter. No intimation of this work had been communicated to his firm and they would be glad to have knowledge of any results. It might be of interest to Dr. Rosenhain, and to members in general, that for more than two years Messrs. Wood, Bros., had been experimenting with electro-osmosed clay, *up to the point of actually building glass pots for large optical glass melts which were now almost dry enough for use in the furnace.* They had had admirable results with pots of smaller sizes and hoped shortly to bring their experiments to a conclusion, by doing full size melts in the large pots.

Regarding the plotting of his results using the equilateral triangle, as suggested by Dr. Rosenhain and also commented on by

Mr. Stott, he would say he had considered the method and recognised its value; but as he had found his own method of graphing of the greatest use in his own work he proposed to adhere to it. The equilateral triangle graphs could easily be constructed if required, as the actual values of the results were given in the papers.

Dr. Rosenhain also pointed out that none of the glasses dealt with were founded upon the well-known $6SiO_2,R'_2O,R''O$ formula, and therefore lost value on that account. He entirely disagreed with Dr. Rosenhain on this point, and the whole of his results went to show that for a glass of the alkali-lime-silica type the formula $5SiO_2,R'_2O,R''O$ was far superior as a working basis to the old Benrath formula. Particularly was this the case in optical glasses, as the glass $6SiO_2,R'_2O,R''O$ was prone to devitrification. The wide use of batches founded on the Benrath formula had, in his opinion, led to glasses too rich in silica, with all their attendant evils.

The remarks of Dr. Rosenhain with regard to the volatility of silica during melting were highly instructive, as were those of Mr. Frink and Mr. Coad-Pryor. He could bear out the evidence of this volatility from the point of view of glass analysis. The fact that silica was often found in the regenerators and flues of tank furnaces certainly seemed to add weight to the evidence of volatility, but he thought it would be interesting to have some microscopical examination of the deposits. There was always the liability of finely-divided sand grains being carried bodily out of a tank by the currents of air or gas. Microscopical examination would show whether the flue deposits were minute sand grains or sublimed silica.

Mr. Oakden brought up the matter of freeing glass from bubble and he could only say, with all glass-makers, that he was still in search of the royal road. He could commend several papers on "Bubble" which had appeared in the abstracts of the JOURNAL to the notice of Mr. Oakden, and he hoped that possibly in the near future the matter might be discussed in a full meeting of the Society. It was too large to enter into at the present juncture.

Replying to Mr. Frink, he would say he would be happy to collaborate in the work of the Glass Research Association as far as time and circumstances permitted, as he was always pleased to help the industry forward as far as he was able.

"*The Composition, Drying and Firing Shrinkage, Porosity, and Density of British Fireclays suitable for Glass Furnace Refractory Materials.*"

By Edith M. Firth, B.Sc., F. W. Hodkin, B.Sc., and
W. E. S. Turner, D.Sc.

Discussion.

Mr. S. N. Jenkinson said he was quite sure all present would thank Dr. Turner and his collaborators, Miss Firth and Mr. Hodkin, for the information which had been brought before the meeting. He would like to point out to the members that this work had been done very economically. He felt that there were cases where men of science had spent a lot of money and produced a very small result. Here, however, on quite a small grant, a vast amount of work had been done, and, further, he believed that there was still more to follow. He would ask the members present to give Dr. Turner and his collaborators a very hearty vote of thanks.

In connection with the paper, he would like to make remarks on two of the clays, since he himself had actually endeavoured to put into use in commercial practice pots made from quite a variety of British clays. Coalbrookdale, for example, he had found to be quite a good working clay, showing a steady shrinkage, yet a shrinkage which was continuous. The clay, so to speak, moved all the way up the firing range. He was under the impression that in practice a clay in which the shrinkage took place gradually was much to be preferred by manufacturers. The Kilmarnock clay, on the other hand, was one which dried very rapidly during the process of pot-making, and in consequence was not easy to work.

Mr. W. J. Rees remarked that he did not think the statement made by the President, that in the past scientific men had spent a lot of money and had done little work, was at all a fair statement of the position. In any case, it was very gratifying to know that at the present time very much more use was made of scientific results in industry, and he was quite sure it would be of great interest to the authors of the paper to see how quickly their results would come into application in the refractory materials industry. What had been detailed to the members that afternoon would readily impress them as involving an enormous amount of work. Yet it was only those who had done similar work who could realise the amount of work which had been involved in the production of that paper. There were very many points of interest which might arise during the discussion of the results. In attempting to draw definite conclusions on the clays there were several factors of importance to be considered. It was certainly true that the impurities present in the clay had an enormous effect on its properties, particularly on the shrinkage and on the porosity, and it would be interesting to compare the amount of fluxes present in the different clays with the rate of shrinkage.

It seemed to him that the research had reached a very interesting stage; but really of still greater interest would be the results if the measurements could be extended to 1500° and 1600°. It was in that region that entirely new results might be expected. For example, over-firing might be expected to occur in some cases, and about this phenomenon of over-firing, or "bloating" as the clayworker termed it, there was very little known. At that stage gases were evolved, but as to what were their nature we were as yet without information.

Another point of very considerable interest in the results presented was the possibility of being able to compare the behaviour of the siliceous and the aluminous fireclays. The Specification which the Society had issued rather emphasised the value of aluminous fireclays for glass refractory materials, but he thought it should be clearly understood that an aluminous fireclay was not so refractory as the siliceous type. This fact might in certain cases be of considerable importance. If, as might be the case, the aluminous fireclays began to soften under load at comparatively low temperatures, then for certain purposes, that is, where a load had to be borne, the siliceous fireclays would be more useful than the aluminous. It was certainly true that some of the aluminous fireclays would fail because they would collapse. In conclusion, he would like to remark that the paper had been of extreme interest, and he was quite sure that it was on correct lines, because the investigation had been begun right from the bottom.

Mr. S. N. Jenkinson, replying to Mr. Rees, said he thought it was still true that money had been actually wasted in scientific research. It was, of course, also true that the manufacturer wasted money in not taking advantage of scientific results. The scientific man obtained certain facts, and he expected the manufacturer to apply them. If they were not presented, however, in a form which the manufacturer could assimilate, the investigations were rather wasted efforts.

Mr. E. A. Coad-Pryor said he would like to ask Dr. Turner if he could give a little more additional information about the preparation of the clay before the shrinkage test. It was a fact that if two clays were made up and their shrinkage measured at once, one clay might appear to have taken up more water than the other in the preparation. If, however, the clays had been kept for some time, it might be found from the changes which would take place during the keeping that when made up into test pieces the physical properties, in particular the shrinkage, would be different from those obtained when the clays were not kept in storage. This, perhaps, was a point which might be dealt with. There was one other matter he would like to mention, namely, that it seemed a pity someone did not attempt to devise a proper method of measuring plasticity definitely. It might be true that the amount of water which the clay contained when in a convenient working state gave an indication of the plasticity, but there were notable exceptions.

Mr. S. Evers, as a manufacturer of fireclay materials, said that he did not rise in order to give information, but because he wanted to know something. He would like to ask why, in the Specification for Refractory Materials issued by the Society, it had been thought desirable to specify that the grog should be made of tempered clay and that nothing in the nature of brick materials should be employed. He himself should have thought that brick material used in a pot clay would be extremely valuable, but could not understand why, when one came to consider the nature of tank blocks, it should be thought tempered clay would be better than lump clay obtained direct from the pit and burnt. He should have thought the latter procedure would have been the better.

Mr. W. J. Rees said that, as Chairman of the sub-committee which dealt with the Specifications for Tank Blocks, he would like to answer Mr. Evers's question. The use of brick material was rejected, not because it was brick, but because of the very real danger arising from the risk that old firebricks might be employed. The use of tempered clay made into grog was suggested because of the experience which had been acquired in the manufacture and use of satisfactory tank blocks. It was desirable that grog should be present having the same composition as the bind clay. Tempered clay gave a good angular grog if made up and burnt to 1400°.

Mr. S. Evers admitted that his question had been answered in a large measure, but he would like to remark that if grog could be got from raw burnt in lump form, was it not as useful as using tempered material? When clay was drawn from the pit and burnt it broke down into more angular pieces or more flakily than tempered grog.

MR. S. N. JENKINSON desired to know if Mr. Evers had proved that absolute angular material was necessary.

MR. W. J. REES agreed that raw clay, when burnt, broke up more flakily than if it were made into brick form first of all; but even so, he was nevertheless of the opinion that it was more desirable to make up the tempered grog into the brick form in order to secure material which would dissolve at a uniform rate.

MR. R. L. FRINK, referring to American practice, said that it had been considered best to use old tank blocks rather than grog from burnt raw clay, since the latter, it was believed, tended to cause fissures.

MR. W. J. REES asked to what temperature American tank blocks were fired.

MR. R. L. FRINK replied that the temperature was probably in the neighbourhood of 1300—1350°. Usually, however, he was afraid there was no actual check on the temperature, and the workmen turned off the kiln when they thought it time to go home.

DR. C. J. PEDDLE said he thought the Society was to be congratulated on having had this work carried out. First of all the paper attempted a critical examination of some sections of the Specification which the Society had issued, and this criticism was valuable. The Specifications had had to be based on such data as existed when the committee were at work, and these data really comprised very little apart from the chemical analyses of various clays. This paper had certainly proved that chemical analysis was not, and could not be, the one and only test of the value of a clay. One or two points had struck him particularly. The first was the recurrence of the 900° point. He had himself in some experimental work endeavoured to determine the effect of the size of grog on the clay when fired, and in almost every case he found that refractories could be heated up to 900° with very little expansion. The Chairman had pointed out that Coalbrookdale clay had a gradual shrinkage and thought this a very good feature. He, however, was not at all sure that the glass manufacturer might not even prefer a clay which expanded in steps rather than gradually, for if he knew precisely where the stepped shrinkage occurred he could deal with it.

In discussing the general question of refractories there were one or two things he would like to mention. In the first place he hoped that before long some research would be carried out in regard to what he might call the weathering of pots, that is, the determination of the length of time a pot should be preserved before it was ready for glass manufacture. There was a very great difference of opinion on this subject. He rather feared that the pot-maker was inclined to the view that when a pot was three or four months old it was quite good. That, of course, would be of very great benefit to the pot manufacturer. His own experience, however, in regard to hand-made pots was that they should be kept for at least twelve months before use. If they were used before they were twelve months old it was risky. Certainly he had come to the conclusion, in regard to hand-made pots, that they should have a minimum life before use in the furnace, and he would like to know whether that period of twelve months could be reduced by any preliminary firing.

The most important matter for glass manufacturers who had to buy pots was the effect of the carriage on those pots. He did not know how far the Society could bring pressure to bear on the railway companies to have special pot-carrying wagons so that the pots could arrive in a reasonably good condition, but it would be a very useful thing if the Society could bring any influence to bear on this. Sometimes in a consignment of six or eight pots in a wagon, two, four, or even as many as six would arrive broken in bits. That, however, was not the only inconvenience, because it was quite impossible to determine whether or not slight fissures or cracks had been produced in the others which to the ordinary eye inspection appeared to be whole.

Lastly, in regard to Dr. Turner's reference that thorough use had not been made of the Society's Specifications, he would like to remark that his firm had asked for pots to be made to the highest specification, and that they had found these pots better than the previous ones. He thought probably that other manufacturers would be more inclined to accept the Specification as soon as further results were forthcoming about the use of goods made to specification.

Mr. J. Connolly thought that perhaps the most important factor in regard to both tank blocks and pots was the porosity. He was glad that Dr. Turner had emphasised that afternoon the fact that chemical analysis alone did not lead them very far in deciding on the suitability or otherwise of a clay. When he himself had used pots he had frequently been sent chemical analyses by clay dealers of the clays which they wished to sell him, but had never found any particular advantage from purchasing by analysis. It seemed to him that it was much more desirable to have as uniform a body as possible to the pot, and that the refractory goods should not be made up of particles of very different sizes.

Mr. W. Butler, referring to Dr. Turner's expression of regret that the Specifications had not been employed by glass and also by refractory materials manufacturers, said he thought some notice had already been taken by pot-makers of the Society's work and Specifications. For example, in his own factory, where they had frequently had trouble in the course of their more or less experimental work carried on during the war, he had directed the attention of pot-makers to methods which they might follow. He felt sure that, even if the results of the Society's work had been absorbed but slowly, some progress had been made.

MR. S. N. JENKINSON, referring to Dr. Peddle's suggestion that a manufacturer might prefer a clay where the shrinkage took place suddenly or in steps, if he knew where the shrinkage took place, said he could not understand any manufacturer showing such preference. He did not know how many manufacturers had it within their power to control satisfactorily the distribution of temperature in a pot arch. From his experience of pot arches, at one moment the top of the pot might be shrinking whilst the bottom was not shrinking at all.

MR. HOULDSWORTH (*communicated*) said that the authors were to be congratulated upon their interesting paper with its mass of useful data. One or two subsidiary points called for a little comment.

In the section dealing with the firing shrinkage of the clays, the authors stated that there might be an expansion at certain points and not a contraction, and instanced clays Nos. 8, 9, 13, and 16. The figure for the percentage shrinkage at 110° for clay No. 8 was 6·87, and at 750° 6·64, the difference being 0·23 per cent. On a distance of 9 cm. of the slab this would amount to 0·207 mm. Similarly for clay No. 9 the difference to be measured would be 0·1 mm., for clay No. 13, 0·09 mm., for the temperature range 110—350°, and 0·198 mm. for the temperature range 500—900°. Measurements of similar magnitude would apply to the other clays mentioned as showing expansion effects. The authors did not state what means they used for measuring the distance between the lines, but if the usual method of stepping off the distance with calipers were used, these differences would almost fall within experimental errors. A travelling microscope or similar device would be required to measure them with certainty, and even then the development of exceedingly fine cracks might account for the difference observed.

The authors attributed these expansions to the allotropic changes in the free silica (quartz) present. If one accepted the usual transformation points as stated by Fenner (870° and 1470°), this explanation would not suffice for clays Nos. 15, 10, 2, 5, 6, and 17, all of which had completed their expansions at 750° or earlier.

The authors found it impossible to measure the porosity after firing at temperatures below 600°, but, of course, were using water as the liquid. Probably the porosities below 600° were not important for their purpose. Recently he had had occasion to measure the porosity of raw kaolin slabs dried at 110° and had obtained quite concordant results, using paraffin as the liquid. In any case paraffin would penetrate into the pores more readily than water.

Mr. F. W. Hodkin, replying to Mr. Houldsworth, said that the distances between the lines on the slabs were measured by means of a vernier microscope reading to 0·01 mm., so that the lengths quoted by Mr. Houldsworth were comparatively large. Further, all the results were repeatedly checked, and he could guarantee the measurements correct to 0·02 mm.

As regards the causes of these small expansions, it did not follow, because clays Nos. 15, 10, 2, 5, 6, and 17 showed no expansions above 750° or a lower temperature, that expansions did not occur due to allotropic changes of the silica or physical changes of certain of the minerals composing the clays. Such small expansions might quite possibly be more than neutralised by the contractions occurring. It was certainly true that slight expansions below 750° could scarcely be ascribed to allotropic change. In regard to the porosities, it was scarcely of importance to measure them at temperatures below 600°, and consequently no other liquid than water was tried. In any case, determinations at 500° or lower would have been open to doubt, owing to the very friable nature of many of the clay slabs at such temperatures. It was quite true that paraffin would penetrate into the pores more readily than water under similar conditions, but, in the case of the slabs fired at 600° or above, simple soaking in paraffin offered no advantages over the soaking in water *in vacuo*. In this latter method, freshly distilled water, air free, was used for every batch of porosities determined, and it would not have been an easy matter to obtain similar quantities of paraffin of constant density.

Dr. M. W. Travers (*communicated*): As this paper only contained the results of a part of a series of investigations, discussion of the results was scarcely possible at the present stage, and one could only confirm one's appreciation of the authors' work and the hope that they would find time to carry it to its conclusion without delay. It might at the same time be suggested that they should endeavour to check their laboratory experiments by others carried out under glasshouse conditions. Test pieces of the materials which had been examined should actually be placed in glass furnaces, the general working conditions of which were known, and examined after intervals of several weeks. The "mineralising" action of alkaline vapours, possibly not an unimportant factor, might be studied in this way, and also the influence of time of much greater duration than that of the experiments. The connection between porosity and chemical attack, and the supposed resistance of highly aluminous refractories to chemical attack, required rigid investigation. Refractory materials were of so complex a character, and such was their tendency to form glowing materials, from which stable systems, consisting of *tridymite, sillimanite,* and *corundum,* should be formed, but actually were not formed within the limit of the life of the furnaces or pots, that conclusions as to their behaviour should only be based on the result of actual experiment.

Col. C. W. Thomas (*communicated*): He was afraid, when he lightly sent in some clays for examination, that he had not realised such an extensive piece of work was in hand. However, he was glad to see the results, because they represented the first actual work he had seen in the direction of finding out how different clays were likely to behave when used for glass purposes.

He could not help coming back to the question of physical structure. If one had a wall built of perfect firebricks, but badly put together *as a wall*, it would fail; and he was quite sure that many failures could be ascribed to this sort of cause, and not to unsuitability of the clay used. He thought some tests on the effect of variously proportioned grain-sizes would be of value.

He would, at the outset, congratulate the authors of the paper upon their efforts to clear up the position, hitherto very vague, as regards the selection and blending of fireclays for the manufacture of tank blocks and of glasshouse pots.

While the results attained were not altogether definite, they should afford a good starting point for further investigations which would enable us to move on much more certain lines in dealing with clays for these purposes.

It was a fact, as stated by the authors of the paper, that so far there had been little or no attempt on the part of glass manufacturers to make the Provisional Specification a basis for ordering clays, or goods made from them.

Both the glass-maker and the refractories-maker had, as the results of their past experience, developed a strongly conservative attitude on this point, and he scarcely thought there had been sufficient evidence brought forward yet to convince the former that the trend of the Specification led definitely towards better results in the pot arch or in the tank. Once the glass-maker became convinced of this, the refractories-maker would not be long in responding. The amount of work done by the authors had been very great, and it would require a very careful study of the figures obtained before one could deduce their full meaning. The first thing that was brought out was the complexity of the subject, and it was evident that there were other factors entering into the reactions that occurred of which we had not as yet any definite knowledge.

He believed it would be found that the physical structure of the pot or tank block was of very great importance, and in this respect he considered that more attention might be given to the proportions of different-sized grains in the mass. The strongest concrete was that in which the proportions of particles of a given size were controlled within specified limits, so that there was the maximum of complete contact between all the constituents of the mass. Some such condition should be observed in the composition of a refractory body where physical strength and resistance to liquid fluxes had to be combined. The requirements for a good glasshouse refractory might be summarised thus:—

(1) No trace of fusion of the main structure at the working temperature of the furnace.

(2) Sufficient mechanical strength to carry, not only its own weight, but also to support the weight of molten metal, also at working temperatures.

(3) A chemical composition that would be neutral to the constituents of the glass both in the earlier stages of melting and also when this was complete.

(4) Resistance to the erosive action of the moving molten mass during both founding and working.

(5) Resistance to the action of the currents of hot gas and of cooler air which were to be found in most, if not all, furnaces.

(6) Resistance, in the older types of furnace, to the action of dust and ash.

The majority of British fireclays would satisfy (1).

Those with a reasonably high silica content would satisfy (2).

Providing that the physical structure was satisfactory, many of them would satisfy (3), (4), and (6), but the mechanical perfection of the "bonding" of the mass was of the greatest importance, both in (4) and (6). Resistance to (5) depended on the combination of a sufficient degree of porosity in the body with such a chemical composition that the inner face or skin, under the action of the molten glass, would form a thin, neutral zone protecting the body of the molten metal.

He was glad to see that the importance of a knowledge of the firing shrinkage was brought out. Far too many pot failures must be attributed to irregular or too rapid heating-up in the pot arch.

In studying the results obtained, it did not seem wise to eliminate all particles of clay that failed to pass a 30-mesh. This made the observed results not strictly comparable with the commercial bulk of the clay.

Much more importance attached to the porosity at the working temperatures of the furnace than to that noted at lower heats, and the same remark applies to the shrinkage.

The degree of porosity attained and the range of shrinkage observed within the working temperatures were what affected the life of the pot while under furnace conditions.

In considering the effect of iron, it should be noted that this depended, in the finished article, upon the condition in which the iron was left after burning. Some clays with a relatively high iron content habitually burned more cleanly than others having a lower iron content. Good burning would produce less ferrous silicate than bad burning with the same clay.

It was evident that the standard gradings set up in the Provisional Specifications would have to be modified to some extent. Even the celebrated Grossalmerode clay stood condemned when so judged. As he believed he pointed out when discussing the Specifications with the committee appointed by the Society for that purpose, it was not by any means easy, nor was it wise, to apply to a particular clay the deductions arrived at from a consideration of the results obtained in practice with another clay. This was confirmed by the authors' summary.

A point worth noting was that the typical pot clays of the Stourbridge district which had earned a very well-deserved reputation were, and still were in the main, siliceous clays, and quite distinct from the "fatter" Continental pot clays, which were for the most part aluminous.

In conclusion, he could only repeat that the authors were to be congratulated upon this paper, which he hoped was only the commencement of a scheme of research which would enable the glass-maker to decide for himself the requirements of his own particular case, both from the point of the mixture he used and of the furnace and the working conditions. When this was done, he was quite sure that these could be met from existing clays, either selected in their natural state or after undergoing some degree of purification.

He looked forward with much interest to the results of the further work foreshadowed on the effect of purification, and also, if the authors could find time for it, on the effect of variations in the physical structure of the pot-wall or of the tank block.

Mr. J. R. Clarke (*communicated*): There were two points in connection with the paper to which he would direct attention.

The first concerned Washington's method of setting out the mineral composition of the clays. If the assumption that all clays were mixtures of the minerals stated was justified, then the densities of the clays before firing must be capable of calculation by additive formulæ, involving the percentage and density of each mineral present in the clay. The density of each of the eight minerals could be obtained by ascertaining the density of eight clays and assuming the additive law. If the density of the remaining clays could be calculated with reasonable accuracy, using these particular values, Washington's method of analysis would be upheld.

The second point concerned the structure of the fired clays. An abrupt change in the real density of a clay after firing, such as was exhibited by many of the clays examined, indicated a change in its structure. It might be that the kaolin had disintegrated into its constituent oxides, that these had recombined to form *sillimanite*, that free silica had inverted from *quartz* to *tridymite*, or that any of many other possible changes had occurred. A microscopical examination after each firing would perhaps afford evidence of such changes and would show at what temperatures these changes took place. Crystals might appear in the fired clay, and their identification would help us to understand what happened to a clay when it was fired. If these crystals could not be recognised by eye or by chemical analysis, the X-ray method of crystal analysis which had been developed by Hull might serve to identify them.

Dr. Turner, in the course of his reply, said that he had been greatly encouraged, not only by the reception which the paper itself had had and the recognition by members that a great deal of work had been done, but also because he perceived from the remarks of some of the members that here and there some of the work which the Refractories Research Committee had carried out over a period of several months and had embodied in the Provisional Specifications was reaching, and being utilised to some extent by, the manufacturers of glass refractory materials. It was certainly wisdom on their part to be cautious, but, at the same time, the Specifications had been drawn up as a result of the combined knowledge of many persons competent to deal with the subject. No doubt, as investigations proceeded, those Specifications must of necessity be modified and sections of them even abandoned. Indeed, some of the results which had been presented that afternoon indicated the necessity for distinct alterations in some of the suggestions embodied in the Specification.

There were very few points of detail left to be dealt with, but he would specially like to refer to two which were raised, the one by Mr. Coad-Pryor concerning the preparation of the clay, and the other by Col. Thomas about the exclusion of particles which would not pass the 30-mesh sieve. In order to obtain comparative results with other workers, standard methods had to be adopted, as explained, and therein lay the reason for the mode of preparing the clay and of excluding the larger particles. Nevertheless, he appreciated the significance of the points raised, and hoped to be able to investigate them later.

Col. Thomas's contribution was just the type which he and his collaborators desired. They were made by one with an intimate knowledge of glasshouse refractories, and would be of great assistance in the future work undertaken.

There were also the valuable suggestions of Dr. Peddle that very useful work might be done in connection with the determination of the weathering of pots and on the effect of transport on glasshouse pots. It seemed to him that most probably a good deal of useful information could be collected before any scientific experiments need be conducted. There were many users of glasshouse pots in this country who had some sort of record of the history of their pots, and it should be quite possible, perhaps under the auspices of the Glass Research Association, to collect and sort that data and arrive at certain conclusions in regard to the time necessary for the pot to stand to mature before it was heated up in the furnace. He would also like to thank Dr. Travers for his suggestion that a comparison should be made of the slabs which had been heated in the electric furnace with others to be heated inside an actual glass furnace. He would endeavour to arrange that such a test should be carried out.

Capt. Clarke's remarks concerning the structural changes occurring in the clays after being fired at different temperatures indicated how many were the useful investigations which still waited to be carried out. He (Dr. Turner) himself had hoped to be able to carry out microscopic examinations on sections of the slabs, but the harvest waiting reaping was so great and the hands so few that he would be glad to pass on to anyone who would microscopically examine the fired clays the slabs which had been accumulated. The results should be of first-rate value, and he would welcome the extension of our knowledge in this direction.

There was one other acknowledgment he would very much like to make, namely, to Mr. J. H. Davidson, whose helpful suggestions had been at the service of the authors throughout their work.

Finally, he would like to say that, however impatient they sometimes felt at the delay in arriving at an ideal refractory material or even an ideal clay for a specific purpose, a very great deal of work seemed to be in front of them before that ideal material was achieved. They had set out to examine a large number of clays and to determine at the outset the changes which the clays underwent in regard to shrinkage, porosity, etc. To what extent this information would ultimately be valuable could only be judged at a considerably later stage. There was still the question of the influence of the glass batch changing or modifying the surface of the fireclay material in contact with it. In a glass pot the internal and the external layers were subjected to somewhat different agents, and each had to be investigated. In the case of tank blocks, their surfaces might be exposed to the chemical action of batch materials and to the mechanical action both of the molten glass and also of fine particles of solid material drawn across the interior of the furnace. Each of these agencies had to be investigated separately. In the paper already presented they had attempted to start without any assumptions to investigate first one factor and then another in order that ultimately the whole of our knowledge of the fireclay refractory materials might be built up.

"*The Casting of Pots for Use in Experimental Work on Optical Glass.*"

By ALICE B. TAYLOR.

REPLY TO DISCUSSION.

IN his contribution to the discussion, Mr. Allen has raised so many points of interest that it seemed best in replying to them to take his points separately in the order in which he has put them forward.

In using the term segregation of grog, the author did not refer to segregation in the liquid on standing, which, of course, should not take place in a proper casting slip. The difficulty in the cast pot is the segregation of grog material into bands or layers in the walls of the pot itself, this segregation occurring in the mould, and the subsequent uneven shrinkage of these layers in the pot on firing. It was in order to do away with this segregation that the quick-filling method, that is, casting under pressure, was used.

With regard to the use of sodium carbonate and sodium silicate as against sodium silicate only in kaolin slips, the proportion of salts used was arrived at partly by the trial method and partly owing to discussion on the subject with various persons manufacturing cast articles on the large scale. It was interesting to find, subsequently, that Bleininger, at the Bureau of Standards, U.S.A., used the same proportions of a mixture of sodium silicate and sodium carbonate in casting optical glass pots. The numerous and diverse kaolin articles made at the National Physical Laboratory with this proportion of alkali (0·2 per cent. of a mixture of sodium carbonate and sodium silicate) show no signs of unsuitability. The relative proportion of the two salts to each other does seem to be of importance. (See also H. E. Ashley, "Technical Control of the Colloidal Matter in Clays—The Joint Use of Sodium Carbonate and Sodium Silicate." No. 23, Technical Papers, Bureau of Standards.)

Concerning the experiments, those illustrated in Figs. 1 and 2 were only preliminary experimental methods, and were very quickly discarded. They were made three years ago, as also the experiments on casting with the application of an electric current. Lower voltages than 110 were not tried by the author. She would be interested to know if, with the lower voltage used, Mr. Allen has managed to obtain pots in which some decomposition of the electrolyte did not take place.

It is perhaps desirable to state here that the work summed up in this paper has lasted intermittently over a period of three years, and Mr. Allen's papers on somewhat similar lines have been read and appreciated as they appeared.

As regards complexity of apparatus, the object of the experiments was to devise an apparatus without complications, easy to control, and manipulated by means of the simplest of operations. The continual production of pots to be used in optical glass meltings was an essential, and the pots have been made very easily for some considerable time. The vacuum casting methods appear to the author to entail a somewhat greater complexity of design and control.

It would be advisable, as Mr. Allen suggests, to measure the extra amount of slip taken by the mould under pressure, also the porosity, etc., of the pressure-cast pot in the green state and after firing. The total shrinkage of the pressure-cast pot after firing to 1480° (9—10 per cent.) is less than that of the same slip cast in the usual manner with the same proportion of alkali. The drying shrinkage is very much less, which would seem to indicate that the clay particles are initially in closer contact than is the case in the article cast without application of pressure. It is interesting to know that Mr. Allen finds the vacuum-cast pots to be of a denser structure than pots cast under pressure.

The air bubbles shown in the base of the pots radiographed occurred only when slip below a certain viscosity was used, where the time of filling was very rapid indeed. If, as Mr. Allen suggests, the bubbles were originally present in the slip before casting, the converse would be more likely, the bubbles having less chance of escape in a pot made from more viscous fluid. It is quite easy to regulate the viscosity of the slip so that no bubbles occur. The appearance of the bubbles and their position indicate rather an encircling and entrapping of the air in the mould by the backwash of the slip after striking against the core of the mould.

There is a further point referred to by Mr. Allen, that is, the reason for reducing the pressure after the mould has been filled with liquid. Since rapidity of rise is an asset in ensuring even distribution of grog and clay, enough pressure was put on to send the slip up quickly, but smoothly, without splashing. It was then reduced somewhat. This was originally decided upon partly because a pot cast under a pressure of 15—25 lb. per square inch maintained for a considerable time has a tendency to crack upon the core, and partly to reduce a long-continued strain on the mould. The resulting pots have been quite satisfactory, although it is possible that the same procedure might not work equally well in casting a pot of much greater thickness.

XIX.—*The Factory Inspection of Glassware.*

By W. E. S. Turner, D.Sc.

(*Read at the Stourbridge Meeting, January 21st,* 1920.)

The subject of the inspection of glassware in the factory was first brought to the notice of the author about two and a-half years ago in perhaps an unusual way. At that time a committee had been set up under the ægis of the Ministry of Labour to endeavour to utilise the services of officers who had been disabled and could not be sent back to active operations at the front. A large number of these men were given intensive courses of training in engineering and in metallurgy, and after three months or so were placed in various munition factories as inspectors of materials before the latter passed out from the factory. The author was approached by this committee with the view of providing similar courses of training in connection with the glass industry. It was then that it was realised to what a small extent systematic inspection of glassware was actually carried on. After reflection, it was found necessary to abandon the scheme, since, even if the men were given any sort of training, there was practically no place for them in the factory. The one branch of the industry where systematic inspection was carried out was in connection with the manufacture of optical glass, but here the inspection was undertaken by scientifically trained persons already engaged at the works. It is true that in certain other branches of the industry, particularly that branch which deals with artistic ware, there must necessarily have been carried on some system of inspection, as the price obtainable and the beauty of the goods obviously depended on freedom from defects. Generally speaking, however, glassware inspection has hitherto been carried on only but loosely in this country.

The subject of inspection has also been emphasised in a recent reference made by the Department of Overseas Trade to the attempts of the Japanese glass manufacturers to build up an export trade. It was pointed out that the Japanese manufacturers, recognising that in the past the goods which they exported had frequently been of poor quality, had agreed to set up a system of inspection on articles for shipment overseas. There can be no doubt that if this system of inspection which the Japanese manufacturers are reported to have instituted is carried out in anything like a systematic and satisfactory manner, the result must inevitably be to raise the standard of the glassware made, and so enable them to build up a stable export trade in much the same way that the Germans were able to make advancement by gradually improving their cheap and untrustworthy wares until they were able to turn out those of excellent finish.

Nothing but good could possibly result if British manufacturers likewise would agree to subject their commodities to rigid examination in order that, whatever the class of article made might be, it should not be sent out unless it bore the hall-mark of quality and would give the manufacturer himself satisfaction if he had to buy instead of having to sell the article.

Methods of inspection in the factory may be divided into two classes: first of all, the inspection which is desirable from stage to stage of the operations involved in the production of any one article; secondly, there is the inspection of the finished work. Some classes of goods do not lend themselves to the stage to stage inspection. For example, in machine-made bottles it is difficult to carry out this inspection, and the only rejections that can readily be made are those containing gross errors which are obvious to the man in charge of the machine. There are, however, quite a number of types of glassware which are capable of stage to stage inspection; indeed, such inspection is necessary. An illustration comes to the author's mind based on what he saw in American factories. A very large number of all-glass hypodermic syringes come into this country from America, and the success of the firm making them is in a very large measure due to the thorough system of inspection involved in their manufacture. The process of forming the barrel, of grinding it out, and of grinding also the plunger, consisted of several stages, and at each stage the article went back through a gauging shop, where any deviations from the required size could be detected. In the production of the articles, automatic machinery was not brought into use, but the success of the hand operations was made possible by this thorough examination of each part of the syringe at the different stages and the determination on the part of the manufacturer that no goods which might be classified as second-class quality should be sold from his factory.

In order to illustrate specifically some of the points which needed systematic inspection, the author may refer to four different types of glassware.

(1) *Table Ware.*

The defects which must be looked for in such articles are:—

(*a*) Poor colour.
(*b*) Cordy or wavy metal.
(*c*) Seeds and unmelted batch.
(*d*) Poor annealing.

The first three make themselves so apparent to inspection that the manufacturer has himself entirely only to blame if goods were passed forward subject to such faults.

The defect which has probably caused much more trouble than any other, however, has been the lack of adequate annealing. Most manufacturers of cut-glassware know only too well the loss which had been experienced in the past, due to the fact that an article might fly to pieces after a very great deal of work had been spent on it. If only some method of systematic examination of the state of annealing had been put into operation, most of such cases would not have arisen.

The detection of strain in a glass article depends on an optical method based on the use of polarised light. Instruments for this purpose are in use in quite a number of American factories, and have been used in some German factories. A very simple form of instrument has been devised in the author's department, and he would be very glad to have copies of it made for all manufacturers who desired.*

If every large piece of glassware intended to be cut or decorated were passed through this instrument, troubles due to shattering would very largely disappear. In one factory which it had been the author's privilege to see, very large glass reflectors were first of all annealed in a lehr and given a second treatment in a kiln. It was necessary to drill two holes in the rim of the reflectors, and the presence of any strain would have brought about shattering. Again, after the holes had been drilled, the manufacturer gave the articles a further annealing. The author does not say that such repeated annealing is really necessary, but quotes the case as one where every care was taken to avoid trouble.

(2) *Lighting Ware.*

There is no doubt that a considerable number of British-made electric bulbs, especially during the war period, have not been altogether satisfactory. They were frequently seedy, cordy, and lacking in uniformity in the thickness of the walls, causing difficulties when the bulbs were cracked off. A representative of one of the electric lamp-making companies told the author that they frequently lost as high a proportion as 12 per cent. of the bulbs received at the factory. A large proportion of the breakages was due to strain existing in the glass, and after the firm had itself set up a lehr and passed through it all the lamps received, this source of trouble was almost entirely eliminated.

The faults which are to be looked for in lighting ware are those already mentioned in the previous section. Uniformity of distribution of the glass is highly important in illuminating ware, since the effect of heat on the portions of the glass of different thickness would tend to cause cracking. Annealing has not previously been considered necessary for lead glass bulbs, but there is no doubt that where the walls are not uniform in thickness, annealing reduces the tendency to breakage during the lamp-making operation. In any case, even lead bulbs should either be cooled down quite slowly or should be given some other form of simple annealing.

If the lighting ware is made of opal or of coloured glass, then the density of the opal and its uniform distribution in the glass should be made the subject of test by means of transmitted light.

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* This instrument was described in a previous paper by S. English, this JOURNAL, Trans., 1919, **30**, 258.

(3) *Chemical Ware.*

This type of glass usually needs a high temperature in order to melt and get into good working condition. Some of the glasses from which beakers and flasks are made are very difficult to soften for the purpose of flanging. The difficulty of melting also enhances the frequency with which cordy or wavy glass is obtained. A beaker or a flask which is one mass of cords does not appeal to a customer, even when such an article will stand erect in use. Further, if the beaker or flask is not properly annealed, it will not last long in the rough usage of an industrial laboratory. It may be pointed out, indeed, that however valuable glass might be considered from the point of view of offering resistance to chemical reagents, most articles of laboratory use are not worn out by the action of chemicals, but are broken by shock, either through sudden heating or mechanically. In either case, thorough annealing will reduce the risk. The state of annealing can be controlled by the aid of the polariscope, such as has been mentioned in connection with table ware.

Glass tubing is another form of article which has not yet reached the highest standard possible in this country. Not many firms appear to have applied a system of periodical gauging to the glass tubing in order that the diameter may be maintained as uniform as possible and the walls be of uniform thickness throughout the length of the piece. There are plenty of gauging devices available, and any works engineer could devise a suitable method. Further, it seems to the author that a manufacturer of glass tubing might with advantage occasionally test samples of his own product in a blowpipe at the factory in order to see that it is capable of being worked properly and that it has been completely plained.

(4) *Bottles and other Containers.*

The articles of this class are usually much coarser and less expensive than those referred to in the previous sections. Nevertheless, inspection is very desirable. Gross defects of such a character are to be noticed from time to time in bottles that the articles ought never to have been permitted to go outside the factory. Bad annealing, often accompanied by lack of uniformity of thickness also, is frequent, and this makes itself emphasised during the transport of the bottles. The author has known of cases in which, during railway transit, 20 to 25 per cent. of the consignment has been broken, largely through defective annealing and want of uniformity in the thickness of the bottle.

A considerable amount of work of inspection has been carried out on various types of containers in the author's laboratory, and a series of tests have been drawn up for two or three classes of ware. Out of these various tests some might obviously be carried out on the articles before they leave the factory. Thus the following tests may be applied to different classes of container.

(a) *Narrow-mouthed Ware.*

(1) Uniformity of weight.

(2) Uniformity of capacity.

(3) Absence of seeds, blisters, and cords.

(4) Test of the size of neck by a standard gauge.

(5) Uniformity of thickness.

(6) Sharp edges in the neck.

(7) Cracking test.

(8) Examination in the polariscope in the case of glass other than dark metal.

(9) Determination of bursting pressure.

The need for checks such as the above will be understood. It may be remarked that the cracking test is applied by filling the bottle with water, heating it slowly to not less than 70°, and chilling it suddenly in water at 20°, afterwards repeating the test at 75° and 80° if the bottle has not previously been cracked. Good bottles should withstand sudden chilling from 75° to 20° without cracking.

The cracking test is really a test both of the uniformity of thickness and of the state of annealing, and is the only method of obtaining evidence on the state of annealing when the bottle is too dense in colour to permit of examination by the polariscope.

(b) *Medical Ware.*

The following are tests which may obviously be applied:—

(1) Uniformity of capacity.

(2) Accuracy of graduation.

(3) Uniformity of thickness, especially in the corners of the bottles.

(4) Suitability of the shape of the neck for pouring.

(c) *Wide-mouthed Ware.*

Wide-mouthed ware is comprised of jars for containing preserved fruit, meat, etc., and such articles have frequently to be filled with hot material. It is desirable in such glassware that it shall be strong and that the glass shall have as low a coefficient of thermal expansion as possible. Supposing that a suitable glass has been chosen, it would still be desirable to inspect the ware for:—

(1) Uniformity of thickness.
(2) State of annealing.
(3) Uniformity of weight.
(4) Uniformity of capacity.

The author would specially like to remark that it is not essential every piece of glassware should be inspected before it leaves the factory. Such rigid inspection, indeed, in many cases would be quite impossible, but the tests can be applied to samples of articles taken from each batch, perhaps 25 or 50 out of every 1000 articles.

It is not necessary to go into further detail in regard to methods of inspection. What has been written above should be sufficient to indicate what is generally desirable. The essential principle which the glass manufacturer should have in mind is the satisfaction of his customer, and for this purpose it is desirable that he shall have not only a thorough knowledge of glass-making technique, but also some fairly clear idea of the requirements of his customer and an understanding of the uses to which the article made is going to be applied. If manufacturers would work on this principle and submit their goods to rigid examination, there is no doubt that a very great advance in the standard of quality would be forthcoming before very long.

Department of Glass Technology,
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Discussion.

The President (Mr. S. N. Jenkinson) said that there was undoubtedly a slackness in inspecting glassware. To inspect every article was, of course, out of the question; one in every tray was perhaps enough. He suggested controlling the temperature in the lehr by having a pyrometer at the hot end. It was possible to avoid putting strains into glass by the simple method of doing all the work of shaping while it was still very hot. He thought that there was a tendency in this country to work the glass too cold.

Lieut. E. A. B. Willmer, R.E. (late of the British Government War Mission to the United States), who received a hearty welcome, said that he had done a considerable amount of work in the States on behalf of the glass trade. There, most firms had an elaborate and efficient system of inspection. American firms took great pride in the quality of the goods they shipped. Girls were often employed on this work, and payment to the workers was according to the number of good articles. Still, he did not think that there was in the States any system of inspection such as had been outlined by Dr. Turner. It was usually towards the finished stage that articles were inspected.

Dr. M. W. Travers pointed out the difficulty of deciding whose duty it was to undertake the inspection, whether this should come under the general manager and not under the glasshouse control. Inspection needed someone who knew a good deal about glass. Besides, it was difficult to get inspection done quickly enough.

Mr. W. Proctor, speaking as a glass worker of many years' standing, said that he knew what inspection meant; for they would at times get paid for only 1400 bottles out of 1600 made. With this sort of experience in mind, he did not think there was anything lacking in the way of inspection. It was undoubtedly a great difficulty to get any glass article of uniform weight. He agreed with the Chairman's remark as to working glass hot. In a machine such as the Owen's machine, some measure of uniformity was possible, but with the human machine this was impossible. There were not always the same physical conditions.

Mr. John Northwood said that in the Stourbridge district inspection was regarded as of great importance. They had to discard and reject a good number of articles, particularly in pre-war days, when the standard of excellence of Stourbridge ware was maintained at a high level, owing to foreign competition. During the war the standard had probably declined somewhat. If they were to maintain their reputation for excellent glassware they must give more attention to inspection. During the war and since, they had undertaken various patterns not previously made. This had prevented specialisation. But if they could specialise in their own particular branches, there was no reason why they should not turn out glass as nearly perfect as possible, and equal to anything in the world. They had also to remember that it was necessary to satisfy the requirements of customers. The Germans had specialised to such a degree that the articles they made for special purposes could not be excelled.

Mr. R. H. H. Wood said he had been in the glass trade since 1872, having commenced life as a lehr boy. At that time he did not think it was generally known what the cause of "flying" was. He mentioned this subject because he had had that very day to deal with the case of a man who complained that a bowl he was engraving had shattered at the last minute. It was most important to prevent such things happening. Universities, he said, were worth supporting, even if only one Stephenson were produced in a century. He thanked Dr. Turner for his paper, and thought that the use of such an instrument as that shown would prevent friction with their employees.

Dr. Turner, in reply, emphasised the fact that it was not essential to inspect every one of a group of articles where these were made in bulk, but that 5 per cent., selected judiciously, should be closely examined. In regard to Mr. Proctor's view that uniformity of weight and size was very difficult to obtain in hand-made or hand-gathered bottles, he would point out that means were nowadays available, and coming into use in an increasing degree, for obtaining uniform gatherings of glass. This was achieved through the action of automatic feeding devices.

XX.—*A Device for Measuring the Internal Diameter of Glass Tubing.*

By Verney Stott, B.A.

The regulations issued by the National Physical Laboratory relating to volumetric tests on scientific glassware stipulate with regard to flasks that the internal diameter of the neck at the mark must not exceed certain limits. All flasks submitted to the laboratory for test are examined in order to determine whether this particular requirement has been fulfilled. As the device by which the internal diameter of the neck of a flask is measured may be of interest to those who supply or use flasks, and may prove useful for purposes other than the one for which it was specially devised, a description of it is given here.

The complete instrument is shown in Fig. 2, and consists of a thin-walled brass tube, *A*, in which the rod, *B*, carrying a cone at its lower end, is free to move. A brass ring is soldered into the bottom of the tube *A*, and attached to this are three springy brass wires (see Fig. 3) placed on radii which make angles of 120° with each other. These wires are all of the same length, and at the upper end of each a phosphor bronze ball (*C*) is fixed. As the cone is pushed down the tube it comes into contact with the three balls, and presses them outwards as it descends.* The tube *A* is cut as shown in Fig. 2, in order to allow the phosphor bronze balls and the wires attached to them to move freely in and out.

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* A combination of three spheres and a moveable cone has been used by W. B. Mair (Patent No. 8034, 1908, and No. 8417, 1917) for measuring the internal diameter of ring gauges.

When the instrument is placed with its lower end inside a glass tube, the cone can be pushed in until each ball is in contact with the inside of the glass tube, but when this happens the cone can descend no further. The diameter is then read off on the scale engraved on the rod *B*, the top edge of the ring *D* being taken as the reference point.

A ferrule, *E*, is made so as to be a spring fit on the outside of the tube *A*. This facilitates the measurement of internal diameters at any desired distance from the end of the tube to be measured.

The instrument is graduated and calibrated by the aid of standard ring gauges. A gauge corresponding to any diameter on the range of the instrument is used, and a pointing mark corresponding to this diameter is made on the rod *B*. The taper of the cone being known, or easily determined, the scale can be divided as soon as one point on it has been determined as above. A taper of 1 in 5 on the diameter of the cone has been found convenient. This gives a scale length of 5 mm. on the rod for each 1 mm. change in diameter of the tube to be measured.

When the scale has been engraved, it is checked at several points by means of standard rings. Also, since the balls will wear in use, it is advisable to check the scale from time to time by the above method.

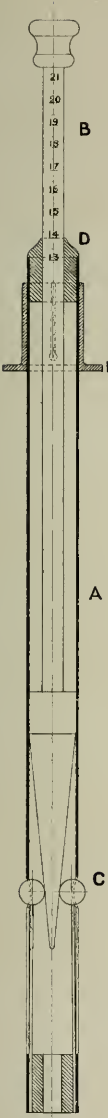
A set of three instruments which have been in regular use for more than twelve months for measuring the internal diameters of the necks of flasks was recently checked by measuring the diameters of several plain ring gauges of known size, with the following results:—

Range of instrument.	Size of gauge.	Measured size.	Error.
9·5 mm. to 14·5 mm.	11·110 mm.	11·2 mm.	$+ 0{\cdot}0_9$ mm.
	14·285	$14{\cdot}3_5$	$+ 0{\cdot}0_{65}$
12 mm. to 18 mm.	14·285	14·3	$+ 0{\cdot}0_{15}$
	17·46	$17{\cdot}4_5$	$+ 0{\cdot}0_1$
17 mm. to 26 mm.	17·46	$17{\cdot}5_2$	$+ 0{\cdot}0_6$
	22·225	22·3	$+ 0{\cdot}0_{75}$
	23·81	23·9	$+ 0{\cdot}0_8$

The amount of wear is thus seen to be small, and if the instruments are checked occasionally, suitable corrections can be applied.

When measuring the internal diameter of the neck of a flask, the instrument is used as follows.

The end of the tube is inserted into the neck of the flask until the three phosphor bronze balls are in the plane of the mark etched



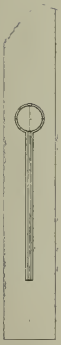


FIG. I.

FIG. 2

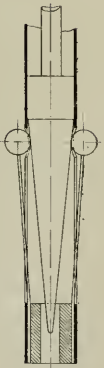
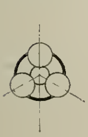


FIG. 3.



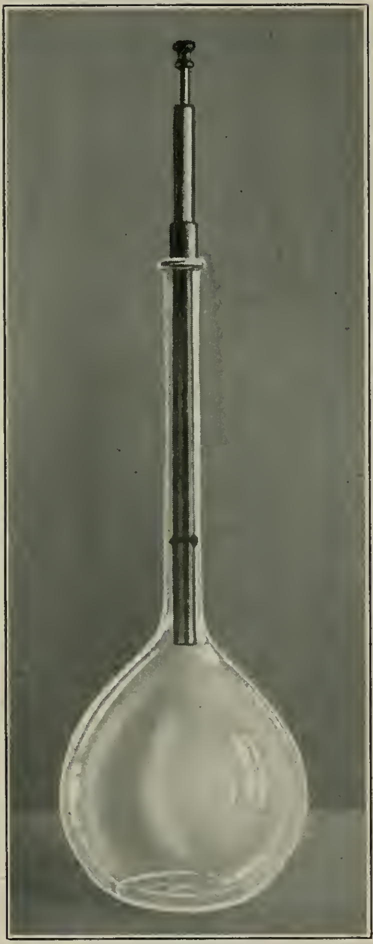


Fig. 4.

[To face p. 262, Trans.

on the flask. The ferrule *E* is then brought into contact with the top of the flask, and so the tube *A* is kept in position with the balls at the right distance inside the flask. The cone is then pushed gently home, and when the balls are felt to have come into contact with the inside of the neck, the reading of the diameter is taken on the scale. After the reading has been taken the cone is withdrawn slightly, the balls close in, and the instrument can then be withdrawn, even if the neck tapers somewhat towards the top. The touch of the instrument is very decided, and when the three balls come into contact with the tube the fact is at once appreciated by the hand which is moving the coned rod. The measurements can be taken with extreme rapidity to an accuracy of ± 0·1 mm. A photograph of the instrument in position in the neck of the flask is shown in Fig. 4.

A disadvantage of this type of instrument is its limited range. The difference between the maximum and minimum diameters which can be measured by any particular instrument is approximately twice the diameter of the balls used. Hence in the case of small tubes, for which correspondingly small balls must be used, the range is somewhat restricted. On the other hand, the instruments are inexpensive and simple to construct, so that if necessary several instruments can easily be made to cover any required range.

If d is the diameter of the balls, then the diameter of the circumscribing circle when the balls are touching each other is $2{\cdot}1547 \times d$. Hence, to obtain the maximum range for any given size of balls, the tube *A* should not be less than $2{\cdot}1547 \times d$ in external diameter. Provided that this condition is fulfilled, the difference between the maximum and minimum diameters which can be measured is $2d-2t$, where d is the diameter of the balls and t is the thickness of the walls of the tube *A*. It is hence advisable to use a thin-walled tube for *A*.

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TEDDINGTON, MIDDLESEX.

[*Received, August 4th,* 1920.]

XXI.—*The Shrinkage, Porosity, and Other Properties of a China Clay after being Fired at Various Temperatures.*

By Miss E. M. Firth, B.Sc., F. W. Hodkin, B.Sc., and
W. E. S. Turner, D.Sc.

The essential constituent of all clays is regarded as a substance having a composition identical with the mineral *kaolinite*, namely, $Al_2O_3,2SiO_2,2H_2O$. Assuming the correctness of the method employed in the calculation of the mineral composition from the results of analysis, it will be seen from our previous paper* that the twenty-seven clays then investigated contained amounts of *kaolinite* varying from 40 up to 82 per cent. If it were possible to obtain a pure *kaolinite*, therefore, and to determine its properties of drying and firing shrinkage, porosity, etc., the information so gained should go far to help to elucidate the results obtained with the ordinary fireclays which are of such heterogeneous composition. Until a pure *clay substance* can be prepared, some additional information may be obtained, however, by the study of a good commercial china clay. Indeed, information about commercial china clay would be valuable in view of the fact that it has a very distinct value as a refractory material. Its *refractoriness* is very high, and it improves the refractoriness of fireclay goods to which it is added. It has already been employed to make small experimental pots, has been used in attempts to improve the lining of glass pots, whilst by isolated makers it has actually been incorporated in the body of a glass pot. We have therefore made a study of the properties of drying and firing shrinkage, porosity, and apparent and actual specific gravity of a sample of commercial china clay. The sample under investigation was found to have the following chemical composition:—

	Composition of the raw china clay.	Composition of the ignited clay.
SiO_2	47·96	54·61
Al_2O_3	36·97	42·09
Fe_2O_3	0·70	0·80
TiO_2	0·10	0·11
CaO	0·10	0·11
MgO	0·14	0·16
K_2O	1·86	2·12
Na_2O	trace	trace
Loss on ignition	12·28	—

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* This vol., Trans., p. 162.

It will be seen that the total percentage of fluxes in the raw clay exceeds 2, and some of the alumina must be present in some mineral form other than *kaolinite*. If we assume that the method of H. S. Washington may be employed for the calculation of the mineral composition, there would be present:—

Orthoclase	11·01
Albite	trace
Anorthite	0·50
Kaolinite	87·00
Limonite	0·78
Serpentine	0·33
Rutile	0·10
Alumina	0·38
Water and Organic Matter	0·02

This method of mineral analysis assumes that 0·38 per cent. of the alumina is free. It seems more likely, however, from the treatment which raw china clays are given before being put on the market, that some free silica rather than alumina might exist.

For the purpose of making test-pieces from it, the china clay was prepared with water in precisely the same manner as described in the previous paper. A very much larger quantity of water was required than was the case with any of the other clays. The actual amount was 49·5 per cent. The prepared clay was very smooth and fairly plastic. On being fired, it changed from the creamy-white colour which it possessed in the raw state to a very slight pink tint between 600° and 1100°, but at 1200° was again dead-white in colour. The fracture of the slabs showed a slightly polished or glazed surface at 1400°, and still more polished at 1500°, with the colour tending to become bluish-white.

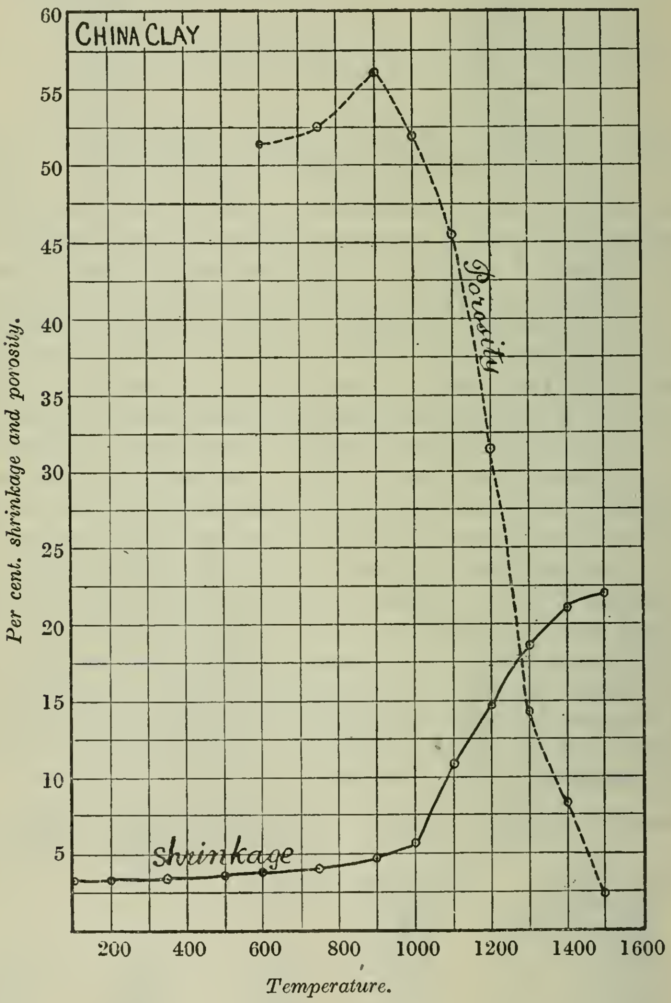
The determination of shrinkage, porosity, and apparent and actual density were made as previously described. The accompanying diagram represents graphically the change of shrinkage and porosity over the whole range up to 1500°, whilst the following table contains the numerical data for all four properties:—

Shrinkage, Porosity, Apparent and Actual Density of China Clay.

	Shrinkage.	Porosity.	Apparent density.	Density of material.
110°	3·30	—	—	—
200	3·32	—	—	—
350	3·38	—	—	—
500	3·61	—	—	—
600	3·92	51·5	1·20	2·46
750	4·14	52·5	1·19	2·53
900	4·48	56·2	1·14	2·56
1000	5·72	52·0	1·25	2·62
1100	10·94	45·6	1·41	2·60
1200	14·71	31·7	1·77	2·60
1300	18·72	14·5	2·19	2·56
1400	21·15	8·3	2·36	2·56
1500	22·08	2·4	2·44	2·51

It will be noted that the shrinkage at first is exceedingly small, and that it increases at a fairly uniform rate up to 1000°, after which it increases rapidly, reaching the high figure, at 1500°, of 22 per cent.

The porosity is of very special interest. At 600° it exceeds already 50 per cent., and reaches a maximum value at 900° of 56 per cent. After that point the porosity rapidly diminishes until, at 1500°, it is very small indeed.



If we compare the china clay with the aluminous clays previously investigated, it will be found that it more nearly resembles Nos. 1 and 2, namely, Mansfield and Kilwinning, rather than Nos. 4 and 7, namely, Ayrshire bauxitic clay and Kilwinning aluminous shale. The very great change in the porosity of the china clay, like that of Mansfield and Kilwinning, is probably due to the effect of the considerable content of total fluxes. Both the Ayrshire and the Kilwinning (No. 7) clays had a comparatively small content of fluxes. In any case, china clay has characteristics peculiar to itself, the most important one disclosed by this investigation being its wide porosity range.

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XXII.—*The Human Factor in Industry.*

By George H. Miles, D.Sc.

(*Read at the Sheffield Meeting, June* 16*th*, 1920.)

During the early stages of the industrial revolution attention was concentrated almost entirely on the material aspect of industry. Invention and research, the application of physical science, and the use of new materials caused an enormous expansion of activity, and completely changed the methods of life of the majority of the people. The inducement of higher wages and the social advantages of town life were incentives more powerful at the time than the many disadvantages involved. In time, however, the effects of long hours, unhealthy working conditions, and the enormous growth of the towns told on the health of the workers; but only when the effects were obvious in physical deformity and stunted growth were active preventive measures taken, and a succession of Factory Acts passed and put into operation.

Physical Well-being.

Although far greater attention is paid to the physical well-being of the workers at the present day, the rapid development of new processes and specialisation in industry demand continued supervision in order to cope with the effects of the changes on the human being. Even to-day the mechanical requirements of industry come first, and the practice is to alter the conditions after the harm has become apparent instead of first making a careful scientific survey of the conditions to be imposed on the operatives and then taking the best preventive measures.

There is room for very great improvement in this direction. I was told the other day that by means of careful statistical analysis it was found that the average age at death in a certain specialised industry was thirty-nine. In the printing trade, for example, there is an abnormally high proportion of illness and death resulting from consumption. It is said that one in ten die from this disease, and in the machine shop it is as high as one in two.

In another industry a firm noticed considerable ill-health and loss of time in a section of its works, and thought that it might be due to the excessive vibration to which the operatives were subjected. On making inquiries to determine this, scarcely any information was available as to the effects of long-continued vibration on the human body, yet much careful research had been carried out as to its effects on metals.

Every industry can show many cases where ill-health and shortened lives are due to unsuitable working conditions.

Not only is the efficiency of the operatives themselves affected, but, indirectly, the ill-health of one member affects the whole family, and in cases of long-continued illness, especially of the principal bread-winner, the standard of living of the whole family is reduced, with corresponding hardship to the individuals and productive loss to the community.

From both the utilitarian and the humanitarian point of view there is a very urgent need for careful investigation, followed by sound preventive measures, to safeguard still further the health of the workers and prevent the new requirements which industry will continue to make from taking their toll of health and life from them.

The aggregate value to the nation of the time and labour lost through illness and early decease, and, in addition, the cost of insurance and treatment, amount to millions, and represent a heavy tax on industry and the community.

Many of the trade unions are dealing statistically with the health problem, but have not the scientific resources to suggest and carry out suitable preventive measures. Employers, too, recognise the importance of the question, and many firms have spent large sums on various methods of improving the health and well-being of their employees—sometimes with very discouraging results. In fact one very disheartened director, when showing me a fine canteen and recreation room that the firm had provided, stated that welfare work was no good. The workers too are sometimes equally emphatic, and ascribe all efforts to improve their lot as veiled attempts to exploit them. Such attitudes are entirely at variance with modern conditions, and the great success that has attended the schemes of some firms shows that the key to success lies in the use of methods which are based on sound psychological principles and in the recognition that the human factor comes first.

The problems are frequently too complicated to be dealt with by individual firms or unions. They can apply temporary remedies, and in this way alleviate much of the suffering and hardship; but it is necessary to go deeper than this—to get at the root of the diseases, and for this they have neither the time nor the scientific equipment at their disposal, and just as they combine to support research associations when dealing with the deeper problems of industry, so there is an imperative need for the formation and support of some body or institution which will deal with the more difficult human problems in industry.

Mental Conditions.

In considering the human factor in industry, however, the physical aspect is only one side of the question, and under modern conditions, so far as immediate efficiency is concerned, the mental attitude of an individual plays a much more striking part. For successful work good physical conditions alone are not sufficient. The mental atmosphere must be right, and for this purpose one of the first essentials is that the man is in his right job. "Round pegs in square holes are always inefficient." They lose interest, or break down through undue and unnecessary exertion, and slackness from either of these causes, harms others and decreases their efficiency. Yet what serious steps has industry taken to ensure that its human material is scientifically guided into the best channels where ability in its own special sphere shall have full scope?

Vocational Guidance.

Six hundred thousand children enter industry and commerce every year at the time of life when they have little or no experience to guide them, and their choice is apt to be made through all sorts of accidental circumstances, irrespective of their real mental and physical qualifications. School records, personal interviews, and the assistance of advisory committees need to be supplemented by careful scientific selection. At present, even where great care is taken, good general intelligence and physical fitness are the predominating factors which determine selection. As a result, many are selected who are fitted for higher grades of work, and others are turned down who might prove excellent at the work if properly trained. There is thus in every occupation an appalling number of "square pegs in round holes."

Owing to the haphazard methods and neglect of the past, much valuable talent has been crushed at the outset or forced into wrong channels. The resulting waste of human energy is appalling. The use of steam power has been studied scientifically for more than a century, and an even more intensive study has been made of the utilisation of electrical energy; but the best disposal of mental and bodily energy, which is by far the most potent factor in a country's welfare, is a neglected science.

Vocational Selection.

Where long apprenticeships are required it is still more imperative that the most careful selection should be made. The Education Committee of the Industrial Council of the Building Industries has fully recognised the importance of this.

Careful psychological tests will determine with much greater accuracy than the present methods the work for which a person is best fitted. A ten minutes' careful test will often reveal more than can be told by parents or teachers who have been acquainted with the individual for years.

At a bicycle ball factory, for example, special tests were applied, and by the more careful selection of operatives the output was increased more than 240 per cent., hours were reduced, wages were increased by 100 per cent., cost of production was reduced, and accuracy increased by two-thirds.

The ideal of service for the community requires as a first essential that the worker is in his right job. It is useless to appeal to a man for his best service if he detests his work and has a grudge against the system which has made no provision for his early guidance and the determination of the occupation for which he is best fitted.

Apart from the effect on the individual, the costs of employment are far too high and represent an enormous waste, owing to the large labour turnover. It has been estimated that in the course of a year this turnover is equal to the whole of the working population. An inquiry into the costs of this part of a business would astonish many a manager, and here there is obviously room for improvement. Both on humanitarian grounds and from a purely commercial point of view the greatest care should be taken in the initial guidance of an individual in his selection of an occupation. When in that occupation the work should be done under as healthy and congenial conditions as possible—mental and physical distraction reduced to a minimum—so that the man can take a pleasure in his work, and, urged by the highest incentives, give his full co-operation and put his whole-hearted energy into the job.

Training for Industry.

Assuming that carefully devised psychological tests have supplemented the present methods of guidance, and that the individual has made the best choice possible, the next step is to ensure that his training is based on the correct methods. Too often the apprentice is left to pick up his job as well as he can. The foreman may be an excellent workman, but be quite unable to impart his knowledge, and in any case may not be acquainted with the best methods, or, what is more important, cannot develop the best that is in his pupil.

The question of the proper training of apprentices is occupying the attention of many trade unions. It is at this stage that improved methods of work, as determined by motion study, can best be introduced. Much progress has been made in this direction, and many well-tested results are available.

Careful selection and training are two preliminaries to success, but no matter how well organised a business may be or how carefully the workers have been selected and trained and their physical welfare catered for, the final result depends on their mental attitude during the working period. Their interest and co-operation are essential.

Psychology in Industry. General Application.

Here are some results which will illustrate this point. At a certain factory there was an excessive loss and waste at the power plant, and a suggestion was made to call in the services of an efficiency expert. The very term "efficiency" is, by its frequent abuse in the past, associated by the worker with a speeding-up and a mechanical exactitude and cramping of outlook that is the reverse of human, and fortunately this idea was not carried out; but the matter was put to the men by one of the managers, who had made a careful study of sound psychological methods. After several discussions, the final result was that each man came to consider himself an efficiency expert in his own line, and worked with the aim of reducing waste, readily accepting suggestions for improvements, and introducing more efficient methods. Instead of the brain of one outsider being at work, the management had stirred the grey matter and enlisted the support of the whole of the operatives. The result was a 50 per cent. saving of fuel, and in other departments a gain of as much as 90 per cent.

In another case, a firm with a thoroughly up-to-date factory had done all they could think of for the comfort and well-being of their employees, but were faced with an unduly large annual loss from defects in the articles which they produced. The old method of discharging an operative for carelessness and incompetency had lost its weight. Labour was scarce and jobs were plentiful, and the operatives were indifferent as to whether they stopped or went. The matter was carefully considered and dealt with scientifically, with the result that the employees worked with the management in every move for efficiency, and by a carefully devised system of incentives to careful work, the quality of the product was so improved and output so increased that the loss was turned to a substantial gain. Another instance of these methods is seen in the success which has attended various co-partnership schemes, where management and workers pull at the same end of the rope; but every case has to be dealt with on its own grounds, and a scheme which may prove eminently satisfactory in one business may be disastrous if applied heedlessly to another.

Now the best schemes can be spoiled by a bad method of presentation, and at the base of any innovation, the employees must be satisfied and guaranteed that they are in for a square deal and, further, that no loss, either to themselves or to their fellow-workers, will arise as a result of the new methods. These conditions are only just. In addition, there must be an incentive to co-operate; and here many employers, and many of the men's leaders too, make the mistake that increased wages is the only incentive that appeals to the worker. Dozens of instances could be quoted where increased pay and shorter hours have been followed by decreased output, and a "bonus" has aroused suspicion. The problems in the labour world to-day are far too complex to be solved by the application of any such obvious and simple remedy, and only by a careful investigation of the psychological factors in each individual case, and a courageous determination to remove the snags that are discovered, can a lasting result be obtained.

Since 1914 all conditions have undergone remarkable changes, and it is only by retrospect that we realise the magnitude of these changes. Ask any employer if he thought in 1914 that he would have acceded to so many alterations in the short period of five years, and he will admit that he is astonished at his change of attitude. Since that date, however, the employees too have had an education as wide and varied as would have taken a generation to accomplish under normal conditions. With the growth of new physical conditions and environment, and with numerous intellectual and emotional changes, the worker of to-day is an entirely different person. For successful work the human element must be considered first and foremost in its widest aspect, and full account taken of the play of instinct, emotion, motive, and aspiration.

The war has demonstrated in no uncertain manner the value of all working towards the same end. A man who has felt the comradeship of a helping hand when in difficulties and has had a demonstration of the irresistible force of a body of men united in order to accomplish the same end realises the tremendous dynamic energy in co-operation. It is the duty to the management to utilise this power, which is ready to hand if the right means are used.

Application of Psychology to Special Problems.

Now the desire to co-operate and the acceptance of its desirability are not alone sufficient. Modern industry cannot be run on good intentions, and while co-operation will do much to improve matters, industry will not be content with this alone. In every branch new methods of working are increasing output, and this increase, where carefully planned, is also to the advantage of the worker. Wherever there is a human being, in factory, mill, or office, there is a chance for some improvement in method which in the aggregate makes for increased output, better goods, and improved working conditions. The worker will probably say at first: "I've been at my job twenty years, and no one can teach me anything about it." The management, too, will say in a hopeless sort of way something like this: "It is impossible to increase output because the output is limited by the speed of the machinery." Such statements show to what an extent modern industry is obsessed by the idea of the importance of machinery as contrasted with the importance of the human being. The machine responds to the care or neglect of the operative, and the quantity and quality of the work produced, even in the most mechanical process, depend in the end on the efficiency of the operative.

In most processes, too, there are some points in the operations at which the skill of the worker determines the rate of flow of the material. By discovering these points and carefully eliminating unnecessary movement, the work can be accomplished at a much greater rate with less fatigue to the worker. But even here there are pitfalls. There are many cases where motion study does not repay the trouble it involves. It is necessary to discover the critical point, so to speak, at which its methods will produce the best results, and, further, to consider what effect on the general flow of material such an alteration will have, and, what is more important still, how the change is going to affect the worker's interest. Frequently the introduction of well-planned rest pauses will also act beneficially. All workers take rest pauses, but the advantages of regular rest periods suited to the nature of the work and the group of workers are obvious. There is a greater "mass-incentive" when all work together, and a greater relaxation, a greater freedom and relief, when the rest is taken by all in the group, but the application of rest pauses by a chance estimation of the amount and duration will very likely be unsuccessful. It has been shown, for instance, that the best duration of the pause depends on the length of the shift and the character of the work. There are also individual differences. Some workers warm up to the work quickly and tire quickly; others begin gradually, and can do best by keeping steadily on for a considerable period. This fact again illustrates the necessity for better initial selection. It is more than likely that with a more scientific choosing of workers in the first instance, such improvements as eliminating unnecessary movements, training in best methods, introduction of most effective rest pauses, etc., would be far more effectual, by reason of a more homogeneous group of workers.

Perhaps the most deadly evil of modern industrialism from the workers' point of view is monotony, and here again it is possible that some solution, or a part solution, may be found in better guidance in the choice of occupation. Monotony is a term which is used very loosely, and its actuality is largely dependent on the individual and his outlook. Fishing, especially when the catch is small, would be to many persons the height of monotony, but to the angler it is of absorbing interest. So, too, attention to automatic machinery may seem the most hopeless of tasks, but to one with the "machinery sense" well developed there is a surprising amount of interest. This in turn ensures greater efficiency. There is less time lost through machinery defects, and the quality and quantity of the work turned out emphasise the importance of the human factor even in this sphere.

It is obvious that the question of monotony requires much further investigation. It is a pressing question, too, as where monotony is felt by the individual—and it is unquestionably present in far too many instances—output decreases in quality and quantity, and the effect on the worker's mentality is disastrous.

There is also a very real danger that some of the attempts to increase output by systems of so-called scientific management will prove disastrous in the end. The "efficiency expert" goads his victim with time schedules, binds him down to stereotyped tasks which effectively destroy all initiative, in spite of a plausible theory to the contrary, and leaves him a mechanical, but for as long as he will stand it, a very effective cog in the machine. These systems may succeed for a while, but if they are at variance with a healthy conception of human life and activity the reaction is inevitable.

Enough has been said to show that industry bristles with psychological problems that require fuller investigation. Many can be dealt with immediately. Others require fuller and deeper research, and this is the more imperative, as the material is such that a wrong step, however well intended, does not stop at the mistake.

Human energy is the greatest force in industry; it is also the most subtle. A few hasty words, an action that is misunderstood, uncongenial surroundings, the wrong job, and its vitality is gone. The work becomes listless, and the most perfectly planned and scientific system or organisation becomes inefficient.

Management has before it an infinitely harder task than it had in the past, where the results of experience guided decisions and clearly defined the best line of action. The difficulties are, however, common, in a modified form, to all industries. Labour, too, is as much interested as management in their satisfactory solution.

"Field Work."

At present much valuable information is being obtained by research at the universities. Some are devising and testing methods of vocational guidance; others are dealing with problems of mental and physical fatigue. There is a vast amount of information lying hidden in the scientific journals and books of this and other countries that would be of the greatest value to industry. There are basic mental and physical factors which are common to the human organisation, whether employed in a glassworks or a cotton factory, and by a suitable allowance for differences of environment and reaction the principles can be applied practically. This implies careful "field work," so to speak, and inquiry into the different branches of industry by trained psychologists, who can adjust the relationships between the basic factors as determined by research, and working conditions, and thus assist in the application of the principles of the science.

Evidently management and labour at the present day have not the time to devote to the solution of these questions, but would welcome some central impartial body which could give practical assistance by co-ordinating the work, supplying information when required, carrying out research, if need be, giving short training courses in the main principles of the science for manager, welfare worker, and foreman, and, when required, sending trained investigators to co-operate with management and labour in the solution of any special difficulties.

With this aim in view it has been proposed to establish a National Institute of Psychology and Physiology. An active Organising Committee has been formed, and a Scientific Committee, which has the assistance of those who are foremost in their respective branches of science, is ready to advise and suggest the best methods of work and research. There is close co-operation with the Industrial Fatigue Research Board, and plans are being made for co-ordinating the research work that is being done at the universities. The Institute also has in hand arrangements for securing the services of a number of trained psychologists, who will carry out investigations and research under the guidance of members of the Scientific Committee, collect information on the subject, and put it in a form suitable for direct application.

In this way trustworthy information of the greatest value to industry concerning the human factors will be obtained, and at the same time the advice of those who have made a thorough study of their subject will be available to assist in solving many of the problems which confront management of the present day.

Discussion.

Mr. E. A. Coad-Pryor gave a brief example of the use which a psychological test would have. Some time ago he had to make up a few samples of refractory materials, and as he could not buy them he had to make them from stock. He engaged a pretty good boy, who, he thought, had every prospect of being an intelligent worker, and got him to make moulds and cast pots. He then engaged another boy and trained him to do the same thing, thinking it would be a good thing if each boy made his own moulds and cast his own pots. The result was not very satisfactory. Then he got one boy to make all the moulds and the other to cast all the pots. The result was far worse than before. He then changed them round, letting the boy that cast the pots make the moulds, and *vice versâ*. After a little experiment he found one boy was extremely good at moulds, but could not make the pots, and *vice versâ*. There seemed to be no difference in the boys; they both had the same kind of recommendation and had very similar interests, which the expert who applied his tests would have discovered at once. There must be a number of similar cases, even in small works, and it might be worth their while to employ an expert psychologist. Was there machinery existing for determining how to devise suitable psychological tests for a particular job?

Probably it was not a long business, and the previous experience of the psychologist would help him considerably. But if it meant that a considerable amount of research work had to be done before a test could be carried out, then it would be extremely difficult to apply it where the number of cases to be dealt with was comparatively small. For instance, take the case of a works using a semi-automatic machine and wanting to get a lad to be trained for "gathering." Would the psychologist know all the exact arrangements the gatherer would have to use? He would want to know what particular features in the man's mental and physical qualities would require testing. Was it going to be a long job to determine those factors, so that one could put the matter into operation in a single case or in a number of cases?

Dr. Miles, replying to the first question in regard to the machinery available for psychological tests, said that no machinery was available at the present time, although an Institute of Psychology was in the process of formation. With regard to the ease with which those tests could be obtained, that, of course, was a question of the different operations. For instance, to select a person who would turn out to be a good typist was comparatively easy; but in other cases a fair amount of research work might be required. Dr. Miles went on to refer to the method of determining these tests by taking a number of workers and applying the tests to these to find how they graded. If the men who came out well in the psychological tests were also high in the employer's estimate, then there was something in common, and the psychological tests could safely be applied to select other operatives. Again, with reference to the records boys brought from school, it did not necessarily follow that if they had a good school record they would do well in business. It might be a case of taking up the wrong occupation. It was therefore necessary to devise more exact tests, and in time it would be possible to carry out tests in industrial life that would give results unobtainable by present methods, where even a good worker often failed to show up to his best. There was one further point he would like to mention. Business men wanted their results quickly, but he would ask them to consider how long it had taken them to attain their present position in the industry. The chief drawback of scientific research from a business point of view was its slowness; but the man of science must be cautious and careful at his work. He must do it thoroughly in order to secure a firm groundwork for present needs and for future advance.

Dr. C. J. Peddle added his appreciation of the paper by Dr. Miles. He very much regretted that there were not more actual glass manufacturers present, who might be able to speak of their own experience where they had tried to carry out some of the ideas Dr. Miles had put before them. He himself was very familiar with cases in the works where changing a man from one job to another had been a distinct advantage, not only to the man himself, but also to the work in general. It had never been a practice in works to look after men in that way, to see how they were drawn towards one thing or another. He was greatly interested in what Dr. Miles had said about the children who entered industry each year. The children came along. They wanted a job and took it up, perhaps because their sister or brother or friends were working in the same mill or works. They came along and got a position as well, yet they might be absolutely unsuited for it.

Of course, one had to fight against another factor, and that was that a man entering into a new kind of industry might not be encouraged to determine his own fitness for any particular type of work, but might take a job for which he had no aptitude for the sake of the money attached to that work. He had known cases of that description where a man, for the sake of the money he could obtain, would take up uncongenial employment rather than employment that would be congenial to him. From that point of view he was very interested to learn that industrial problems were being tackled from the psychological point of view.

Mr. W. Butterworth, jun., said that the most useful results would probably be attained by one or two psychologists taking up one particular industry and devoting all their time to it. Mr. Coad-Pryor dealt with isolated cases. He himself thought that there were not many isolated jobs. For most jobs in glassworks a test applied to one thing could be applied to another. The gatherer, of course, was a widely employed operative in all the glass trades, but for the results obtained it was not necessary for each small works to employ a special psychologist. It would be more convenient to have one psychologist at the National Institute, or to have two or three psychologists, say, devoting their time to devising tests for the different occupations in the glass trade. Manufacturers could help them and could work in conjunction with the Glass Research Association. He did not know if anything of that sort was intended, and he would be glad to know something about the organisation of the tests.

Dr. Miles remarked that the question had been considered by a number of firms, and that some works in the country were thinking of introducing trained psychologists to deal with such questions, and also with difficult working conditions. These tests could then be applied and good results obtained that would be the key to success. As experience was obtained, these tests would become more and more standardised.

Mr. J. Connolly observed that he happened to be a member of a committee in Manchester that had for its object the care of boys after leaving school. A very great deal lay in the fact that parents, when a boy left school, very often made an application for him to leave before his time had expired. They looked upon him as someone to bring more grist to the mill. It was more a matter of how much more money he was going to earn than what he was going to be. There was a great deal in what Dr. Miles had said, but he did not think it required a psychologist to undertake the work suggested. There might be a man in the works who understood all the scientific side of the work, but who had very little knowledge of the human factor. During the past forty years he had had a great deal of experience with apprentice lads. What would appeal to one boy would not appeal to another. The boy who gave the most trouble was the boy who had never been shown how to do his work thoroughly, and who therefore did not take an interest in it. He had taken the iron out of a lad's hand many a time and told him how to use it properly. That lad would take a greater interest in his work afterwards, because he had been encouraged. When one saw a man doing his work and whistling over it, then the best was being got out of him. When a man thoroughly understood his work he enjoyed it. That brought them to another side of the question—if a man enjoyed his work it was not monotonous, whatever he was doing. If they wished to live they must remember the three principal needs—the need of skill to earn a living, the need of knowing what was going on in other countries, and the need of knowing what other men were doing. Obviously, the skill to earn one's living was a practical one, and here the university came to their aid. Whether the university ought to become a trades school depended upon what they meant by a trades school. There was every reason why the teaching of trade should be encouraged. The living they earned was only a door to life. The carpenter or the glass-maker did not wish to live in a heap of wood or glass, or the teacher in a number of schoolrooms, but each wished to exercise his calling in a common well of ideas.

Capt. A. S. Giles said that the question of apprenticeship and of learning the ideas of the boys and young men who were just entering the industry seemed a very important point. In some glass factories a boy would rather come in as a boy and earn a certain wage than enter as an apprentice and get to know the ins and outs of the trade. He could not understand why. During his period in the Army after the Armistice he had had to be a schoolmaster, and one of the things he had had to do was to teach mechanics. He started off by asking his pupils why they wanted to be mechanics. It was surprising how many failed to give a satisfactory answer.

Dr. Miles said the question of training and apprenticeship had to be considered. It was generally recognised that it was essential to train, but by directing them to the points of interest. The idea was not simply to teach them to make a thing, but also to get them interested in its relationship to the trade. He had come across a striking evidence of that in the West Riding in one of the large dye works, where a man dealt with one of the minor processes all day long. It was proposed to relieve the apparent monotony of the process by giving the man an insight into the part his special job played in the whole series, so that the worker would feel he was actually taking part in the industry. That was a good idea. Many disputes occurred because the employer and the employee did not see each other's point of view, not only of work, but of human life. Psychology would thus be of the utmost value, not only to employers, but also to workers. It was necessary to investigate the problems in co-operation. It was no use trying to introduce new methods without the support of the men. It would be a very wrong move to do that. If one could only get the men to co-operate with the management, then one would be able to bring a new force into the industry, because it was the human element that counted. When they grasped that fact they could go ahead and do anything, and in that lay the key to a large number of questions, for the solution of which a knowledge of psychology was a very great help and advantage. He did not say it was going to do everything, but it would go a long way to solve many problems of the industry.

Miss F. H. A. Turner (a visitor), speaking as a welfare worker, said that for some time past they had had a standardised scheme of training, and in that scheme there was a training in psychology. To a certain extent she thought that possibly a firm employing a welfare worker might have a psychologist included in that welfare worker.

Mr. E. A. Coad-Pryor suggested that it might possibly be of service if the meeting passed a resolution directing the attention of the Glass Research Association to the psychological aspects of the glass industry, coupled with the suggestion that the Association should communicate with the National Institute of Psychology on this subject.

A resolution to that effect was duly passed.

Appendix.

Since the above was written a number of firms, recognising the importance of the work, have generously given promises of financial support for this pioneer work, covering a period of five years, and it has been decided to establish the Institute so that the preliminary work may begin. Temporary headquarters are at 329, High Holborn, London, W.C. 2, and a wide appeal for funds is now being made in order to deal adequately with these most urgent and complicated problems.

XXIII.—*Note on the Density of Soda–Magnesia Glasses.*

By C. J. Peddle, D.Sc., F.I.C.

This note is written as a contribution to the discussion upon the paper entitled "The Density of Soda-magnesia Glasses," by English and Turner.* These authors find in a series of glasses 6 mols. of SiO_2, x mols. of Na_2O, y mols. of MgO (where x falls from 2 molecules to 1 molecule and y increases from 0 molecule to 1 molecule), that as the Na_2O is replaced molecule for molecule by MgO, the SiO_2 remaining constant, there is a continuous fall in density. They point out that this is different from the case of the CaO glasses, where the density rises continuously when CaO is substituted molecularly for Na_2O in the series $6SiO_2,xNa_2O,yCaO$.

The writer is able to confirm these results from a series of glasses of the type $5SiO_2,xNa_2O,yMgO$, x falling from 1·75 to 1 molecule and y rising from 0·25 to 1 molecule, which gave density results as follows:—

	Molecules.			
Melt No.	SiO_2.	Na_2O.	MgO.	Density.
200 *A*	5	1·75	0·25	2·453
B	5	1·625	0·375	2·448
C	5	1·50	0·50	2·444
D	5	1·375	0·625	2·439
E	5	1·25	0·75	2·433
F	5	1·00	1·00	2·421

It will be seen that as the Na_2O is replaced molecularly by the MgO there is a fall in density, and when the results are plotted in terms of molecules per cent. of MgO, a straight line is obtained, just as was the case with the $6SiO_2,xNa_2O,yMgO$ glasses investigated by the authors mentioned above.

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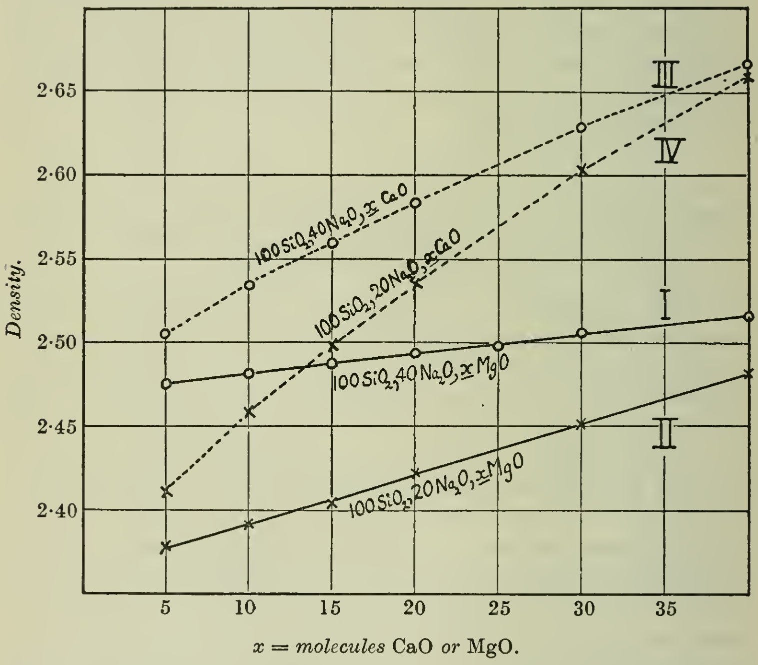
* This vol., Trans., p. 153.

When the densities of the glasses of the $6SiO_2,xNa_2O,yMgO$ series * are compared with those obtained by the writer for the $5SiO_2,xNa_2O,yMgO$ series, it will be observed that the glasses of the latter series have the higher density when corresponding values of x and y are taken in each series. Thus the introduction of silica, molecularly, into this type of glass lowers the density.

The statement that magnesia differs from lime, inasmuch as it lowers the density of glass, is only true in the particular type of glass investigated where the silica remains constant molecularly and the soda is replaced molecularly by magnesia or lime. Thus, in effect, (1 molecule of CaO) – (1 molecule of Na_2O) increases the density and (1 molecule of MgO) – (1 molecule of Na_2O) decreases the density where silica remains constant molecularly. Consequently, a molecule of Na_2O added to a glass of this type has a greater effect in raising density than the addition of a molecule of MgO, but a smaller effect than a molecule of CaO.



It is possible to have a continuous increase in density with an increase in the amount of magnesia in a glass, just as with lime,

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* This vol., TRANS., p. 155.

although the rise is not so marked as with the last-named oxide. Thus the writer found in the two molecular series:

(1) $100SiO_2,40Na_2O,xMgO$,
(2) $100SiO_2,20Na_2O,xMgO$,

where the molecular silica–soda content remains constant in a series, while the MgO content (x) rises from 5 molecules to 40 molecules, that there is a continuous increase in density.

In the accompanying figures, curves I and II show the densities of the glasses of the MgO series plotted against molecules MgO. Curves III and IV show the densities of the corresponding glasses of the CaO series.*

The following facts are evident:—

(1) In glasses where the molecular SiO_2 † and Na_2O content remains constant, increasing the molecular content of either MgO or CaO raises the density.

(2) Comparing either the two MgO series or the two CaO series, where the SiO_2,MgO or SiO_2,CaO content is the same in two glasses, the one with the higher molecular Na_2O content will have the higher density.

(3) The rate of increase of density per molecule of CaO added is much greater than the rate of increase per molecule of MgO added.

(4) The rate of increase of density diminishes in both the MgO and CaO glasses as the amount of magnesia or lime increases, and this diminution is most marked in the series containing the most Na_2O.

(5) In two like series of CaO and MgO glasses, the lime glasses have a higher density than the magnesia glasses.

THE RESEARCH DEPARTMENT,
DERBY CROWN GLASS CO., LTD.,
DERBY.

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* This vol., TRANS., p. 22.

† In the paper by English and Turner, the apparent density which SiO_2 has in glass, as deduced by the author, was quoted wrongly as 2·40. The figure quoted by the author in the text was 2·22. Actually this should have been 2·20.

XXIV.—*On certain Surface Effects in Glass, probably produced by Reheating in the Glory Hole.*

By Dr. MORRIS W. TRAVERS, F.R.S.

(*Read at the London Meeting, May 19th,* 1920.)

A FEW weeks ago, Dr. R. Whytlaw Gray, while showing me some experiments on the deposition of fog particles on glass surfaces in the laboratory of Eton College, directed my attention to a curious phenomenon. A powerful beam of light was projected on to a microscope slide, and the particles were examined by reflected light by means of a high-power microscope. The first surface of the glass was in focus, and it was noticed that while some slides were scratched on the surface, others appeared to be minutely pitted.

We examined a number of slides and pieces of photographic glass plate together, and found that in every case the pitting appeared on one side of the plate and the scratches on the other. The result of photographing the images is shown in the figure, *A* representing the pitted surface, *B* the scratched surface.

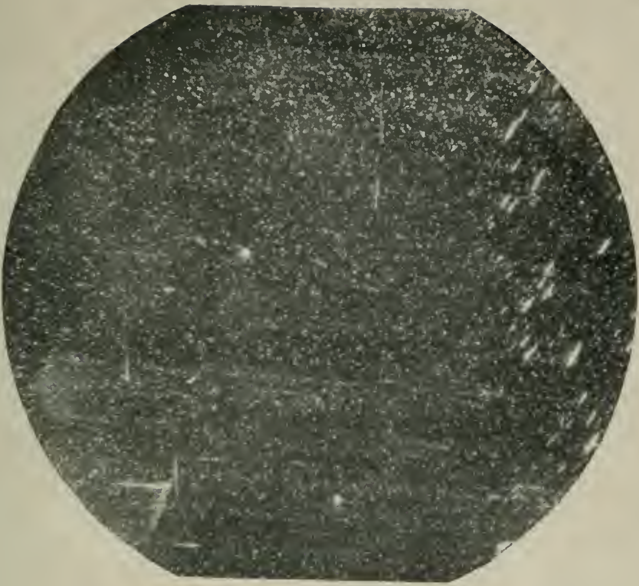
Further careful examination showed that the apparent pitting was due to the formation of a minute seed consisting of bubbles, measuring about 1 μ, immediately below the surface. As a provisional explanation I suggested that it was due to the evolution of gas from the outer surface glass in the process of reheating the ball before blowing the cylinder. The scratches on the reverse side, the inside of the cylinder, would then be due to the action of the wood block used in the flatting process.

To check this idea, we picked out from the laboratory glassware pieces in which the glass would certainly have been reheated in the glory hole in the process of manufacture. Such articles as clock-glasses, which are cut from large globes, always showed this pitted appearance, on the *outer* surface only. The pitting did not, of course, appear in plate glass.

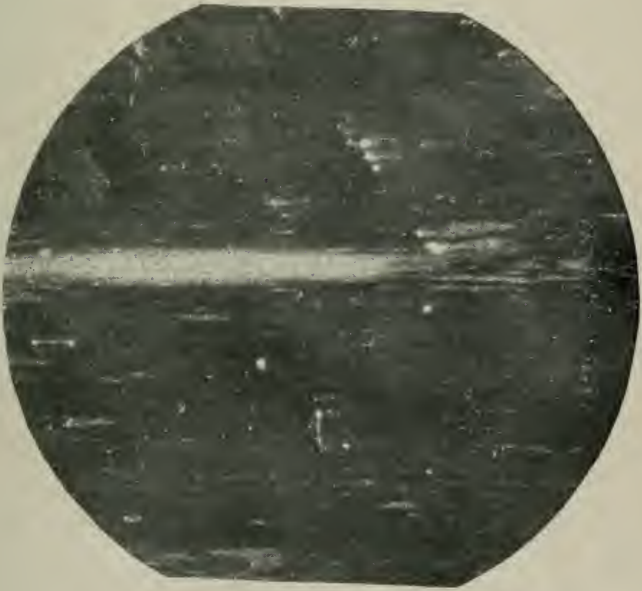
All glass which is colourless and which contains manganese must probably also contain oxygen in solution, the oxide or silicate of iron and manganese being in equilibrium with this oxygen,

$$2MnO_2n(SiO_2) \rightleftharpoons 2MnOn(SiO_2) + O_2,$$

$$2Fe_2O_3n(SiO_2) \rightleftharpoons 4FeOn(SiO_2) + O_2,$$



A



B

[To face p. 284, Trans

the reactions proceeding from left to right as the gas is evolved from the glass. If the glass in the pot is "plain" and of "flint" colour, and the temperature suddenly rises, the equilibrium is disturbed in the same direction, and the effect called "after boil" is produced. When the glass is worked in the air–gas lamp flame the glass does not become hot, or mobile enough, to produce any effect, and if bubbles are formed it is only because the glass is already seedy. In the oxy-hydrogen flame even plain glass will show a "boil."

In a direct-fired glory hole intense radiations are given off from the burning coal or coke, and to these radiations glass is opaque. Reheating in a direct-fired glory hole may therefore result in intense heating of the surface of the glass, which would account for the phenomenon observed. It is worth further study, and I should be glad to receive samples of glass for examination, with information as to their history and method of treatment, but I should be equally pleased if anyone else would take the matter up. The subject is of importance to microscopists and to window-glass makers, for the result of the phenomenon must be to reduce both the brilliance of the glass and also its transparency. As to whether varieties of glass, other than soda-lime glass, exhibit the effect is also worth study. Samples of lead glass reheated in the pot mouth do not show it, but the so-called "sulphuring" of lead glass in the direct-fired glory hole may be partly due to something of the kind.

BEACON HALL,
PRIORY GARDENS,
HIGHGATE, N. 6.

DISCUSSION.

MR. R. L. FRINK said Dr. Travers had, in his opinion, not stated an hypothesis, but a fact; for in a series of investigations made on photographic dry-plate glass concerning the relative value of different methods of manufacturing them, the conclusions reached were as follows:

That when the glass was made by the ordinary hand method and was blocked by wood blocks which were kept fairly moist, there was a reduced amount of the specking or tiny seeds appearing on the outside of the ball, even upon reheating. Without question, the seeds referred to and the blemishes shown in the photomicrographs were those produced by dust taken up from the block of the ball. However, in many photographic plates there would be found to exist minute specks or particles, these usually occurring because of dust existing on the flattening stone or logger, and which became embedded in or adhered to the surface of the glass.

The scratches arose during the flattening, Dr. Travers had stated. This was proved by the fact that where photographic plate was made by the machine process, one seldom, if ever, found the minute seeds on the outside surface, but any blemishes on the outside of the cylinder were of a specky character, and the inside was scratched by the flattening block. To prove this, flattened portions had been produced by making the cylinders sufficiently large to be capable of being split through their diameter, and then flattening them in the inverted position, thereby bringing the interior of the cylinder into contact with the flattening stone and the exterior into contact with the flattening block. The result was the production of scratches on the exterior of the cylinder and the specks on the interior. Further than this, he had seen photographic plate, as well as microscope slides, made by the sheet-drawn process when no flattening was required, and on this occasion neither blisters, specks, nor scratches were found.

Dr. Travers (*communicated*): He could not accept Mr. Frink's hypothesis as an explanation of the facts which he had brought forward. The presence of the scratches which appeared on one surface of the sheet glass, but not on the convex surface of the clock glass, was only of interest as showing which was the inner surface of the cylinder from which the sheet was formed. That the seeds appeared on the outer surface of the sheet glass and of the clock glass precluded the possibility that they were due to dust taken up in the flatting process. It was possible, however, the settling of dust on to the highly mobile layer of glass on the surface during the process of re-heating might have something to do with their formation.

XXV.—*Some Developments in the Study of Glass Technology in the Year* 1919–1920.

By W. E. S. Turner, D.Sc.

The glass industry in this country has entered during the past year on perhaps its most critical period, and everyone is anxious that the opportunities offered during the war shall not be lost. The artificial conditions existing during war-time no longer remain, and in order that the promise of better times shall be fulfilled the industry has to assume a determined fighting spirit.

During the war tremendous developments took place. It was shown that this country could produce, and had actually done so in a very short space of time, chemical glassware second to none in the world so far as chemical resistance was concerned, and it needed only the patriotic efforts of an encouraging public to make that industry a permanent one.

Further, the progress in the manufacture of optical glass may truly be described as wonderful. In a very short period of time, glasses, superior to those produced at Jena, have been made on a commercial scale in this country, and also in very great variety.

The natural protection, however, which the industry received during the war has largely been removed, and we have some foreign countries where the rate of exchange is exceedingly low ready and anxious to send in their wares once more, to the disadvantage of the industry in this country. If it were a question of quality only, then we could very reasonably hope to maintain our market intact. Unfortunately, the rate of exchange is outside the power of control of the manufacturer, and until some measure of protection against unfair competition is provided he has perforce to rely on the quality only of his goods and the determination of the public to encourage his efforts.

The glass industry is therefore thrown on its own resources. Despite difficulties which may surround the present situation, it is to be hoped that a determined fight will be made to develop it. Undoubtedly the greater the interest which the manufacturer has in the actual art and knowledge of glass-making, the more certain is he likely to seize opportunities of making his manufacture a success. All educational efforts and all attempts to encourage research will therefore meet with the support and approval of every thoughtful manufacturer. We have to train up a new and young generation to carry on the fight. It is to give some information as to what is being done towards this end that it has been thought helpful to reproduce the following report of the work carried on under the Delegacy for Glass Research at the University at Sheffield.

FOURTH ANNUAL REPORT OF THE DELEGACY FOR GLASS RESEARCH.

THE fourth year of the Glass Delegacy's work has been one of steady development rather than of outstanding events. The Department is waiting expectantly at the present time for room in which to expand and to develop its work further. The tasks which lie at hand are many, and new fields still remain as yet unexplored.

Although the output of research work has probably been greater than in any previous year, perhaps the chief feature of the year's working has been the recovery of the University's educational work. In October, 1919, seven students entered the Department with the view of preparing for the Degree course in Glass Technology, whilst two others entered for the Diploma course. The majority of these men had seen service in H.M. Forces, and their work during the year has been marked with keenness and enthusiasm; some of them are sons of manufacturers, and it is hoped that they will set an example which will be followed by many other manufacturers' sons throughout the country.

In the present year, also, the proposed Degree course comes into full operation, having been approved by the Court of Governors. The course presents interesting features in that it is possible for a student to spend part of his time at the University and part at a works, so that he may combine practice with theory, whilst the course also makes it possible for a student to earn sufficient funds during one part of the year to enable him to study during the other.

The question of accommodation, both for teaching and research, has been brought up at each of the three Delegacy meetings held during the year, and much thought has been exercised on the subject. In the summer of 1919 a small wooden structure was erected in order to house crushing and grinding machinery which was placed at the disposal of the Delegacy by the Society of Glass Technology. This small plant has greatly facilitated the research work connected with fireclays and refractory materials.

In order also to furnish some additional accommodation for students, part of the graduating and etching room was equipped with shelving and cupboards so that a certain amount of chemical work could be undertaken by students engaged on experimental melting. These extensions scarcely touch the fringe of the need for more room. Not only is the work at the present time carried on under unsuitable conditions, especially the chemical and physical testing work, but it has to be borne in mind that practically two separate staffs are at work, the one in temporary laboratories at St. George's Square, the other at Badger Lane. If the work could be brought together in one building, a considerable economy of effort would be effected.

During the year the Department lost the services of Mr. J. D. Cauwood, M.Sc., who has accepted an important appointment at Messrs. British Glass Industries, Ltd., and of Captain J. R. Clarke, M.Sc., who served as research physicist to the Department. For lack of funds these two particular posts remain unfilled at the present time. On the other hand, the great extension of the teaching work called for further assistance, and Mr. A. Cousen, B.Sc., A.R.C.S., was appointed Assistant Lecturer, and to assist with the increasing volume of commercial work Miss D. Holdsworth, B.Sc., was appointed as a Research Assistant. Mr. G. S. Duncan, M.A., B.Sc., was also appointed Assistant Secretary to the Department. The Delegacy desires to thank Mr. Dennis Wood, F.S.A.A., for continuing to act as Honorary Lecturer in Glass Works Accountancy.

The Delegacy has to acknowledge the continued generosity of the West Riding County Council, the Association of Glass Bottle Manufacturers of Great Britain and Ireland, the Yorkshire Flint Glass Bottle Manufacturers' Association, the Yorkshire Bottle Manufacturers' Association, and the British Laboratory Ware Association. Not only have these Associations generously continued their grants, but the Association of Glass Bottle Manufacturers of Great Britain and Ireland and the Yorkshire Flint Glass Bottle Manufacturers' Association have made generous donations, the first-named of £300 and the second of £162 10*s*., towards the reduction of the debt on the original building fund account.

Wood Prize.

It is with special pleasure that the Delegacy makes reference to its acceptance of a sum of £105 8*s*. 6*d* from the Society of Glass

Technology, raised as a testimonial to Mr. Frank Wood. The money has been invested so as to provide for the award annually of a Wood Medal and Prize.

The Systematic Research Work of the Department.

The following papers have been published during the course of the year:—

"The Annealing Temperatures of the Lime-soda Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.

"Further Investigations on Chemical Glassware," by Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

"The Year's Progress in Glass Research under the Auspices of the Glass Research Delegacy" (Report for the Year 1919), by W. E. S. Turner, D.Sc.

"The Glass Industry of North America," by W. E. S. Turner, D.Sc.

"The Properties of the Lime-soda Glasses," by J. H. Davidson, M.Sc., and W. E. S. Turner, D.Sc.

"The Durability of the Lime-soda Glasses," by J. D. Cauwood, M.Sc., J. R. Clarke, M.Sc., Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

"The Heat Expansion of Soda-lime Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.

"A Simple Apparatus for the Detection of Strain in Glass," by S. English, M.Sc.

"The Influence of Lime on the Value of Young's Modulus of Elasticity for the Lime-soda Glasses," by J. R. Clarke, M.Sc., and W. E. S. Turner, D.Sc.

"Some Experiments on Glass for Lampworking Purposes," by J. D. Cauwood, M.Sc., J. H. Davidson, M.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

"Magnesia–Soda Glasses," by J. H. Davidson, M.Sc., F. W. Hodkin, B.Sc., and W. E. S. Turner, D.Sc.

"The Annealing Temperatures of Magnesia–Soda Glasses," by S. English, M.Sc., and W. E. S. Turner, D.Sc.

"Glass for Optical Purposes (A Note)" (*Trans. Faraday Soc.*, 1920), by W. E. S. Turner, D.Sc.

In addition to these papers, five others were read before the Society of Glass Technology with the view to publication. It will be seen, therefore, that there has been a greater output of research work than in any previous year.

The Department was asked to supply to the Glass Research Association a list of the problems which it has in hand, and this list is given as an appendix. It includes a considerable variety of problems, the solution of many of which has already been attempted.

Work for Manufacturers.

The increase noted last year in this side of the Department's activities has been fully maintained. Indeed, at times the laboratory has been congested with such work, but it is work that is very well worth doing, for it not only increases our experience, but also brings us into actual and close touch with factory problems. During the course of the year several pieces of research of considerable length have been carried out on widely different subjects, such as the utilisation of waste products, the preparation of lampworking glass, and an investigation of fireclays for refractory articles.

During the year 158 cases of inquiry have been dealt with, making a total to the end of March, 1920, of 533. The inquiries may be classified again as:—

(1) Inquiries and consultations involving no experimental work	90
(2) Examination of raw materials and the investigation of problems arising during the manufacture of glass ...	63
(3) Determinations of the physical properties of glass ...	5

Educational Work.

Reference has already been made to the influx of students taking full-time University courses. It is a matter for considerable satisfaction that the reputation of the Department is growing so that it is becoming known throughout the world. At the beginning of the session 1919–20 three students from India were amongst the entrants, whilst we have also had an Australian student and a Chinese, and various inquiries are being made by prospective students from India, Japan, and America.

The numbers of students who entered for the various courses in the session 1919–20 were as follows:—

Degree Students		11
1st Year	7	
2nd „	3	
3rd „	1	

Diploma Students		4
1st Year	2	
2nd „	2	
Special Courses		8
Total		23

The local centre courses have been carried on at Barnsley, Leeds, London, Mexboro, and Sheffield. The London centre represented a new venture, and, all things considered, it has had a successful beginning. A desire has been expressed by the students and by the Governors of the Sir John Cass Institute (where the class is held) that the classes shall be continued during the coming session. The number of students at some of the centres has somewhat diminished, but it is very gratifying to record that those who attended were very keen, and the majority of candidates who presented themselves for examination have been successful. For the First Year Course examination, 16 candidates presented themselves; 12 were successful, 5 gaining distinction. For the Intermediate Course there were 6 candidates, 5 of them being successful, 1 gaining distinction, whilst all 4 candidates in the Final Course were successful, 2 of them gaining distinctions. The total number of students enrolled in the classes was 94.

In addition to the systematic local centre courses, a special course of six lectures, intended to prepare the way for a systematic course, was delivered at Stourbridge on "Labour-saving Devices and Machinery in the Glass Industry." The first of these lectures was attended by more than 200 persons, and this large attendance was maintained throughout the series. It is proposed to continue these special courses at other centres.

The Lamp-working School.

In the Lamp-working School the following is the record of registrations:—

Day Classes.	
No. in the School April 1st, 1919	15
No. admitted April 1st, 1919, to March 31st, 1920	20
No. not retained after month's trial	5
No. placed in positions	19
Evening Classes.	
Total number	9

Practically all the pupils admitted were disabled soldiers.

THE UNIVERSITY OF SHEFFIELD.

RESEARCH DELEGACY IN GLASS TECHNOLOGY.—Income and Expenditure Account.

1920.—March 31st.	£	s.	d.	1919.—March 31st.	£	s.	d.	£	s.	d.
To Salaries (Nine members of scientific staff, assistant secretary and typist)	2,527	1	7	By Balance brought forward ..				171	5	4
,, Laboratory Expenses	1,078	2	5	1920.—March 31st.						
,, Printing and Stationery	45	13	6	By Grants :—						
,, Advertising	25	15	3	Government	50	0	0			
,, Examination Expenses	2	3	8	University	500	0	0			
,, Incidental Expenses	6	17	8	Department of Scientific and Industrial Research ..	1,200	0	0			
,, Wages	309	0	9	West Riding County Council	500	0	0			
,, Rates and Insurance	142	17	4	Association of Glass Bottle Manufacturers of Great Britain and Ireland ..	250	0	0			
,, Telephones	11	12	6	Yorks. Glass Bottle Manuf's. Assn.	250	0	0			
,, Coal, Light, and Water	752	15	7	Yorks. Flint Glass	250	0	0			
,, Cleaning	87	11	0	Society of Glass Technology ..	400	0	0			
,, Travelling Expenses	106	3	6	British Laboratory Ware Association	100	0	0			
,, Grant to Lamp-working School (see below) ..	100	0	0	Local Managers	30	0	0	3,530	0	0
,, Bank Interest and Commission	4	1	9	,, Students' Fees				230	3	6
,, Architects' Charges	21	0	0	,, Tests and Researches				571	0	1
,, Repairs	4	3	0	,, Donations				10	0	0
				,, Balance forward				713	5	7
	£5,225	14	6					£5,225	14	6
1920—March 31st.										
Balance forward	£713	5	7							

LAMP-WORKING SCHOOL.—Income and Expenditure Account.

1920.—March 31st.	£	s.	d.	1919.—March 31st.	£	s.	d
To Salaries and Wages	214	8	0	By Balance forward	6	8	1
,, Laboratory Expenses	184	19	11	1920.—March 31st.			
,, Balance forward	85	2	4	By Grants :—			
				Delegacy in Glass Technology (see above)	100	0	0
				,, Students' Fees	343	0	0
				,, Goods sold	35	2	2
	£484	10	3		£484	10	3
				1920.—March 31st.			
				By Balance forward	£85	2	4

In connection with the development of the lamp-working industry, Mr. English has developed a new type of burner specially suitable for cracking-off machines, whilst experiments have also been in progress with a machine for semi-automatically sealing on the arms to glass taps.

The Financial Position.

The balance-sheet for the year 1919–20 is appended. It shows a deficit of more than £700, and would have been far heavier but for the fact that two posts falling vacant were left unfilled. As costs are rapidly mounting, the position is becoming rapidly worse. The Delegacy feels sure that members of the glass industry will not permit the Department's work to be badly impaired for lack of funds when once the facts are known.

APPENDIX.

LIST OF RESEARCHES EITHER PLANNED OR ALREADY IN PROGRESS.

I. *Chemical Researches.*

A. *Fundamental Researches.*

*Determination of the specific effect of silica, boric oxide, lime, magnesia, zinc oxide, lead oxide, baryta, alumina, zirconia, soda, and potash on the durability of glass, and the effect of mixtures of these oxides.

B. *Specific Researches.*

*1. Investigation of a satisfactory autoclave test for the determination of durability.

*2. Investigation of satisfactory etching reagents.

*3. Determination of the best compositions of glass bottles and dishes for various purposes.

II. *Physical Researches.*

A. *Fundamental Researches.*

*1. The study of the annealing conditions for glasses containing the oxides mentioned under I, A.

*2. The determination of the coefficient of expansion, refractive index, density, crushing strength, and elasticity of the glasses referred to in (1).

*3. Determination of the viscosity and working range of glasses containing specific constituents.

---

* Researches on these subjects have already made progress.

B. *Specific Researches.*

*1. Determination of the bursting pressures of bottles of definite composition and form.

*2. Correlation of the cracking temperatures of bottles and other forms of containers with form, relative thickness, and other factors.

*3. Design of simple apparatus for testing condition of annealing.

III. *Researches on Glass Production.*

A. *Fundamental.*

*The effect of different proportions of cullet on the properties of glass.

B. *Specific Researches.*

*1. The production of a satisfactory lampworking glass.

*2. Preparation of opaque coloured glasses for artificial human eyes—opal, red, blue, amber, black.

*3. Utilisation of various waste products in glass manufacture.

*4. Production of homogeneous glasses of composition included under I, A.

5. Experiments in the electric melting of glass.

6. Investigation on the production and properties of fused arsenic sulphide glass.

IV. *Research on Glass Refractories.*

A. *Fundamental Researches.*

*1. Systematic investigation of the composition and physical properties (drying, shrinkage, firing, contractions, porosity, density, and refractoriness) of different types of British fireclays, untreated and after treatment.

*2. Investigation of a satisfactory quantitative method of determining the corrosion of refractory materials.

3. The effect of specific batch ingredients in corroding fused refractory materials.

B. *Specific Researches.*

*The properties of refractory stone used for furnace blocks.

V. *Furnace Tests.*

A. *Fundamental.*

The systematic study of existing commercial melting and annealing furnaces with a view to their improvement.

---

* Researches on these subjects have already made progress.

B. *Specific Researches.*

The permeability of glass pots to furnace gases.

VI. *Light and General Engineering Problems.*

*1. The design of a machine for making T-pieces, taps, etc.
*2. Design of an improved burner for cracking-off operations.
3. A study of the effectiveness of different types of mixing machine with a view to an improvement in design.

XXVI.—*Automatic Feeding Devices for Glass-making Machinery.*

By Homer Brooke.

The author's attention has been directed to an advertisement in an English paper of the incorporation of a new company and its issue of shares to manufacture glass by automatic methods.

The utilisation of a flowing stream of molten glass from the furnace and cutting from it predetermined quantities of glass at a definite rate (30 to 90 per minute), the portions of glass then being served to automatic machines to make ordinary articles of glassware, has been successfully carried on for a number of years in the United States and Canada under patents granted to the author in the United States, Canada, Great Britain, France, Belgium, and Germany. The object of this paper, whilst asserting once more the priority for the invention due to the author and also directing attention to the greatly increased production which can be obtained by its use, is in the main to bring to the notice of all glass manufacturers that the patents have now expired and are therefore open to all freely to utilise them.

The invention of the flowing device led to a very great increase in the daily output of automatically-made glassware, with a great reduction in the labour costs.

The author would like to illustrate this increased production by testimony which was made in the Courts of the United States, where it was necessary, on various occasions, to carry on litigation in order to protect the rights of the invention. The references extracted from the reports are as follows:—

---

* Researches on these subjects have already made progress.

> "The saving is enormous and production very great.
>
> "Thus, with reference to the quart fruit jars, four machines having Brooke devices, with four workmen, produce nearly as many pieces as were produced on 10 machines with 20 men when the old hand-gathering method was used.
>
> "In producing vaseline jars and other small ware, five machines with five men could produce nearly as much ware as did 15 machines and 30 men when the old gathering operation was used.
>
> "In producing glass lids, five machines having the Brooke device, with two men, produce as much ware as 42 machines and 168 employees by the hand-gathering operation.
>
> "In producing liners, nine machines having the Brooke device, with two men for all these machines, produce as much as was produced by 35 machines and 140 men and boys by the old hand-gathering method.
>
> "And the cost of production to-day by the Brooke device is enormously less than by the old hand-gathering method, although the cost of labour is much higher.
>
> "Certainly this may truly be designated as a revolution in this art. In order to secure the right to do this business, the Hazel-Atlas Company obtained a licence under the patent in suit, and has, so far, paid over $146,000 in royalties under that licence.
>
> "Likewise Ball Brothers began using this device without a licence, and then were sued in Indiana. At the conclusion of the arguments in the case, Ball Brothers took a licence under the Brooke patent, paying $7500 in cash, and in the short period from January, 1914, to April, 1918, have paid as royalties $30,076 on ware made on the machine shown in the Bingham Patent 1100345.
>
> "And it also appears that the Graham Company was brought squarely in contact with the Brooke patent in a suit. That company was engaged in the manufacture of narrow neck bottles, such as soda and beer bottles."

The following reference to my work also gives some idea of the capability of the device:—

> "Brooke was the first to devise means to permit those machines to work to capacity. It was the entirely original

> and novel idea of the patentee to operate upon molten glass *flowing continuously* from the furnace and dropping in a stream-body or column through the air, by severing that *flowing stream* at a point below the outlet, and distributing the cut-off portions into moulds.
>
> "As we all know, the art of making glass articles is an extremely old one. During all the years and centuries that this art has existed and been practised, there was, until Brooke's time, only one means successfully used for securing the desired small batches of molten glass from the large mass in the furnace."

It will certainly be of interest to British readers to know that the author was born in Yorkshire, where his father, William Brooke, was a well-known mechanic employed by large and successful industries.

William Brooke migrated to America in 1849 with his family, and was immediately employed in a large glass-works near New York City. There he made many improvements in glass manufacture. When he died, in 1863, his business of making moulds and glass machinery was continued by his son, that is the author, up to 1899 in New York City. In 1876 the Centennial Medal was awarded to the author in recognition of his work in the improvement of moulds and machinery. Far and away the most important of these various inventions is, however, the flowing device. It does away with the necessity of the hand-gatherer, who is subjected to very great fatigue from the heat of the furnace.

The author will be happy to assist any manufacturer of glass containers who cares to consider the utilisation of his flowing device now that the patents have expired and the process is generally available.

227, Summit Avenue,
Mount Vernon, N.Y., U.S.A.

XXVII.—*The Development of Various Types of Glass. Part VI. The Interaction of Silica, Lead Oxide, and Sodium Oxide.*

By C. J. Peddle, D.Sc., F.I.C.

In the early days of the optical glass industry, only two types of glass were available for the use of the optician, namely, the "Hard Crowns," distinguished by low refractive index and low dispersion, and the "Straight Flints," which had a high refractive index and a high dispersion. All the glasses in use with scarcely an exception, from the lightest crown to the densest flint, could be arranged in a single series in which the dispersion continually increased with the refractive index. The classical work of Abbe and Schott from 1882 onwards placed new glasses at the service of the optician of such types that choice could be had of several glasses identical in mean refractive index but varying in dispersion, or, *vice versa*, glasses with constant dispersion but with the mean refractive index varying. Although these newer glasses found immediate and increasing employment in optical combinations, yet the "Hard Crowns" and "Straight Flints" were still needed, and to-day they find considerable use in the hands of the optician. This, coupled with the fact that they are fairly simple in constitution, led the author to commence his researches with work on the "Hard Crowns" and the "Straight Flints." The preceding five papers * dealt with the development of "Hard Crowns." The present paper, together with the four that follow, deal with the "Straight Flints."

The melting of the various glasses was carried out according to the method described in Part I., p. 6. The molecular basis was used for building up the batches, the variant oxide in each series of glasses being lead oxide. This was introduced into the batches as red lead oxide, the material used being the same as that used in the large works melts and of a high degree of purity. Other materials used in the batches, namely, sand, sodium carbonate, and potassium carbonate, were from the same stock as was used for melting the "Hard Crown" series. No decoloriser was used in any of the melts. One innovation had to be introduced in making up the batches, namely, the introduction of part of the alkali oxide as nitrate. When the melts were carried out without nitrate being present, it was found that there was a tendency for metallic lead to separate out, particularly in those glasses containing a high percentage of lead oxide. This lead was found as a metallic globule embedded in the bottom of the pot. Both the sodium nitrate and potassium nitrate used were very good samples.

---

* "The Development of Various Types of Glass. Parts I.—V.," this vol., Trans., pp. 3—107.

The properties of the glasses were investigated by the methods previously described in Papers I. to V.

In order to investigate the interaction of silica, lead oxide, and sodium oxide, two series of melts were carried out according to the scheme outlined below.

TABLE I.

Series $100SiO_2,40Na_2O,xPbO$.				Series $100SiO_2,20Na_2O,xPbO$.			
Melt No.	Molecules. SiO_2.	Molecules. Na_2O.	Molecules. PbO.	Melt No.	Molecules. SiO_2.	Molecules. Na_2O.	Molecules. PbO.
180 *A*	100	40	5	181 *A*	100	20	5
B	do.	do.	10	*B*	do.	do.	10
C	do.	do.	15	*C*	do.	do.	15
D	do.	do.	20	*D*	do.	do.	20
E	do.	do.	30	*E*	do.	do.	30
F	do.	do.	40	*F*	do.	do.	40

The percentage batch composition in terms of oxides is shown below.

TABLE II.

Series $100SiO_2,40Na_2O,xPbO$.					Series $100SiO_2,20Na_2O,xPbO$.				
Melt No.	SiO_2.	Na_2O.	PbO.	Al_2O_3 + Fe_2O_3.	Melt No.	SiO_2.	Na_2O.	PbO.	Al_2O_3 + Fe_2O_3.
180 *A*	62·88	25·15	11·67	0·30	181 *A*	71·91	14·38	13·35	0·36
B	56·31	22·51	20·89	0·29	*B*	63·44	12·69	23·55	0·32
C	50·96	20·39	28·39	0·26	*C*	56·76	11·35	31·61	0·28
D	46·58	18·62	34·57	0·23	*D*	51·34	10·27	38·14	0·25
E	39·70	15·88	44·23	0·19	*E*	43·12	8·62	48·04	0·22
F	34·60	13·85	51·39	0·16	*F*	37·17	7·43	55·21	0·19

Results.

Series $100SiO_2,40Na_2O,xPbO$.

(1) All the batches yielded glasses, the first, 180 *A*, being bubbly.

(2) All the glasses were coloured, the colour becoming deeper as the PbO content increased, showing that a rise in the amount of PbO caused increased pot attack. Glass 180 *A* was light blue and 180 *F* dark green, the others being intermediate between these two colours.

(3) All the glasses were very brilliant.

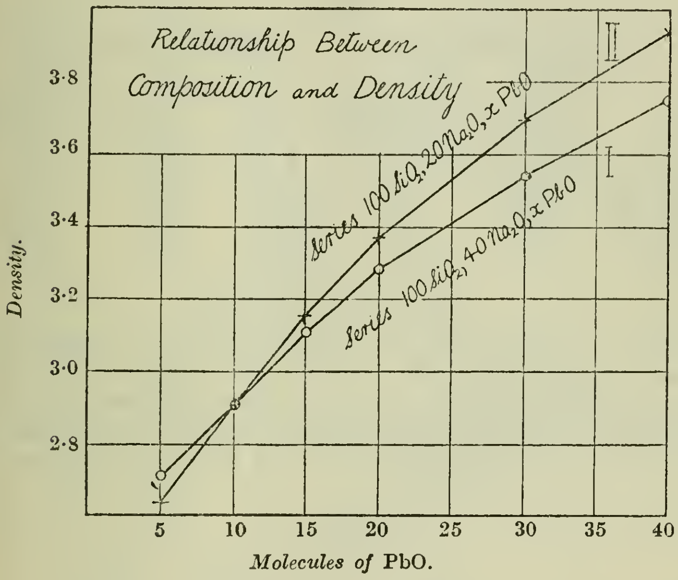
Series $100SiO_2,20Na_2O,xPbO$.

(1) In this series the first glass, 181 *A*, yielded some glass very full of separated silica, and also some unmelted batch was present. All the other batches yielded glasses.

(2) The glasses were coloured, varying from light blue in 181 *B* to dark greenish-yellow in 181 *F*, again indicating increased pot attack as the PbO increased. The colour of each glass in this series was superior to that of the corresponding glass in the $40Na_2O$ series.

(3) The glasses were very brilliant.

Fig. 1.



THE PROPERTIES OF THE GLASSES.

1. *Density.*

The following table shows the densities of the various glasses, and a comparison of the two series is shown in Fig. 1.

TABLE III.

Series $100SiO_2,40Na_2O,xPbO$.		Series $100SiO_2,20Na_2O,xPbO$.	
Melt No.	Density.	Melt No.	Density.
180 *A*	2·710	181 *A*	2·628
B	2·912	*B*	2·911
C	3·112	*C*	3·152
D	3·282	*D*	3·368
E	3·543	*E*	3·690
F	3·756	*F*	3·940

The following conclusions are to be drawn:—

(1) The density increases as the molecular PbO content increases.

(2) Above 20 per cent. PbO (10 mols.), increasing the Na_2O content decreases the density.

(3) The rate of increase in density is greater in the series containing the lesser Na_2O, and falls off as the PbO rises.

(4) Table IV. shows the actual increases in each series for molecular addition and percentage addition of PbO.

TABLE IV.

Series $100SiO_2,40Na_2O,xPbO$.			Series $100SiO_2,20Na_2O,xPbO$.		
Mols. PbO.	Rise in density per mol. PbO($\times 10^4$).	Rise in density per 1 per cent. PbO($\times 10^4$).	Mols. PbO.	Rise in density per mol. PbO($\times 10^4$).	Rise in density per 1 per cent. PbO($\times 10^4$).
5—10	404	219	5—10	566	277
10—15	400	267	10—15	482	300
15—20	340	275	15—20	432	331
20—30	261	270	20—30	322	326
30—40	213	297	30—40	250	348

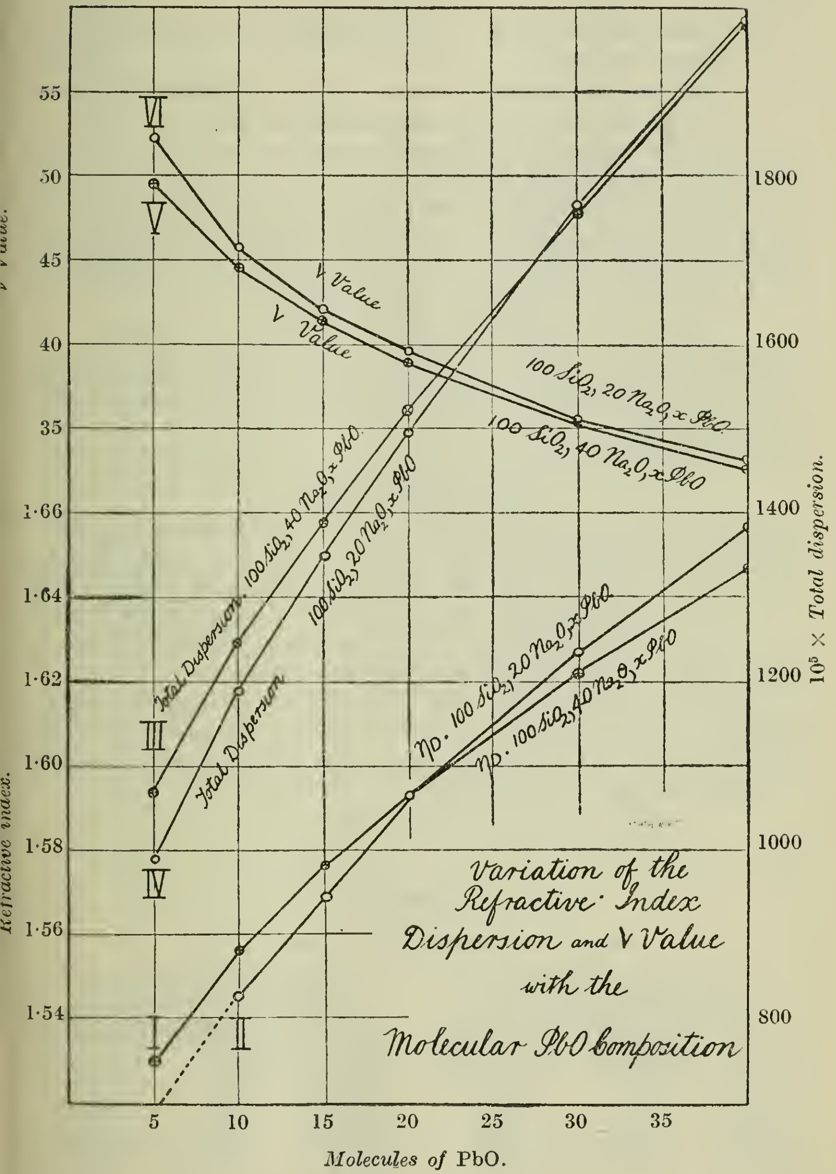
2. *Refractive Index.*

Glass 181 *A*, being full of separated silica, was useless for the refractive index test. All the other glasses in both series were quite suitable for polishing, and gave good results on the Pulfrich refractometer. Table V. gives these results and Fig. 2 shows them in diagram form. The values for 181 *A* have been extrapolated.

TABLE V.

Melt No.	η_D.	Total dispersion $10^5\times$ $(F-C)$.	ν.	Partial dispersion $10^5\times$ $(D-C)$.	Partial dispersion $10^5\times$ $(F-D)$.	β.
		Series $100SiO_2,40Na_2O,xPbO$.				
180 *A*	1·5299	1069	49·57	310	759	0·710
B	1·5558	1246	44·57	360	886	0·711
C	1·5761	1390	41·45	401	989	0·712
D	1·5927	1522	38·94	437	1085	0·713
E	1·6219	1757	35·40	501	1256	0·715
F	1·6472	1980	32·68	560	1420	0·717
		Series $100SiO_2,20Na_2O,xPbO$.				
181 *A*	1·5186	990	52·38	289	701	0·709
B	1·5448	1191	45·74	345	846	0·710
C	1·5691	1351	42·12	390	961	0·711
D	1·5930	1496	39·64	431	1065	0·712
E	1·6272	1767	35·50	505	1262	0·714
F	1·6571	1984	33·12	563	1421	0·716

FIG. 2.


55
50
45
40
35
1·66
1·64
1·62
1·60
1·58
1·56
1·54
ν Value.
Refractive index.
1800
1600
1400
1200
1000
800
10^5 × Total dispersion.
5
10
15
20
25
30
35
Molecules of PbO.
VI
V
III
IV
I
II
ν Value
ν Value
100 SiO_2, 20 Na_2O, x PbO
100 SiO_2, 40 Na_2O, x PbO
Total Dispersion. 100 SiO_2, 40 Na_2O, x PbO
Total Dispersion
100 SiO_2, 20 Na_2O, x PbO
η_D. 100 SiO_2, 20 Na_2O, x PbO
η_D. 100 SiO_2, 40 Na_2O, x PbO
Variation of the Refractive Index Dispersion and ν Value with the Molecular PbO Composition

Curves I. and II. of Fig. 2 represent the variation in η_{D} in the two series with increasing PbO content. It will be observed that—

(1) The refractive index in both series increases as the molecular PbO content increases.

(2) The rate of increase per molecule of PbO added is greater in the series containing the smaller amount of Na_2O.

(3) As the molecular PbO content rises, the rate of increase per molecule of PbO added decreases.

(4) Where the molecular PbO content is the same in the two series, the glass containing the greater amount of Na_2O has the greater refractive index for the *D* line until a PbO content of 20 molecules is reached. Then the two glasses,

$$100SiO_2,40Na_2O,20PbO \quad \text{and} \quad 100SiO_2,20Na_2O,20PbO,$$

have the same η_{D} value, $=1·593$. The refractive indices for the *C* line are not the same for the two glasses, or the refractive indices for the *F* line.

(5) In soda–lead oxide–silica glasses of the type

$$100SiO_2,xNa_2O,yPbO,$$

where x lies between 20 and 40 molecules and y between 0 and 40 molecules, the greater the amount of Na_2O in the glass the less will be the effect upon the refractive index of adding PbO. Similarly, the greater the amount of PbO in the glass the less will be the effect of adding Na_2O. This statement is probably true for all values of x and y capable of yielding glasses.

(6) The respective effects of PbO and Na_2O upon η_{D} for the different concentrations of the two oxides are shown in Tables VI. and VII. The rises in η_{D} per molecule and per 1 per cent. addition are shown side by side.

TABLE VI.

Rise in η_{D} due to the addition of PbO.

	Series $100SiO_2,40Na_2O,xPbO$.			Series $100SiO_2,20Na_2O,xPbO$.	
Mols PbO.	10^5 × rise per mol. of PbO added.	10^5 × rise per 1 per cent. of PbO added.	Mols. PbO.	10^5 × rise per mol. of PbO added.	10^5 × riso per 1 per cent. of PbO added.
5—10	508	275	5—10	524	257
10—15	416	277	10—15	486	301
15—20	332	269	15—20	478	366
20—30	292	302	20—30	342	345
30—40	253	353	30—40	299	417

TABLE VII.

Rise in η_D due to the addition of Na_2O.

Mols. PbO.	$10^5 \times$ rise in η_D per mol. of Na_2O added.	$10^5 \times$ rise in η_D per 1 per cent. of Na_2O added.
5	56	105
10	53	106
15	35	77
20	− 2	− 4
30	−27	−73
40	−50	−154

From these two tables it will be seen that PbO has a much greater effect per molecule than Na_2O. In the case of Na_2O, when the amount of PbO is greater than 20 molecules, adding further quantities of Na_2O causes the refractive index to decrease. Thus if 1 molecule of Na_2O were added to the glass

$$100SiO_2,20Na_2O,10PbO,$$

the refractive index would be raised by 0·0005. If 1 molecule of Na_2O were added to the glass $100SiO_2,20Na_2O,40PbO$, the refractive index would be lowered by 0·0005. It will be seen that in glasses containing 15 molecules of PbO or less the rise in refractive index due to the addition of 1 molecule of PbO is ten times as great as the rise due to the addition of 1 molecule of Na_2O.

Curves III. and IV. in Fig. 2 show the variation in total dispersion $(\eta_F - \eta_C)$ in the two series with increase in the number of PbO molecules. The following points are of interest:—

(1) Total dispersion increases with increasing PbO.

(2) The rate of increase diminishes with increasing PbO.

(3) Where the molecular PbO,SiO_2 contents of two glasses are the same, the glass with the greater Na_2O content has a slightly higher total dispersion.

(4) The rate of increase of total dispersion with increasing PbO is slightly higher in the series containing the less Na_2O.

(5) Table VIII. shows how the total dispersion in the two series is affected by the addition (i) of a molecule of PbO, (ii) of 1 per cent. of PbO at different concentrations of PbO.

TABLE VIII.

Effect upon Total Dispersion by the Addition of PbO.

Series $100SiO_2,40Na_2O,xPbO$.			Series $100SiO_2,20Na_2O,xPbO$.		
	$10^6 \times$ mean rise in total dispersion.			$10^6 \times$ mean rise in total dispersion.	
Mols. of PbO.	Per mol. of PbO added.	Per 1 per cent. of PbO added.	Mols. of PbO.	Per mol. of PbO added.	Per 1 per cent. of PbO added.
5—10	354	192	5—10	402	197
10—15	288	192	10—15	320	198
15—20	264	213	15—20	290	222
20—30	235	243	20—30	271	273
30—40	223	311	30—40	217	302

Table IX. shows the effect upon total dispersion of the addition of Na_2O.

TABLE IX.

Mols. of PbO.	$10^6 \times$ rise in total dispersion per mol. of Na_2O added.	$10^6 \times$ rise in total dispersion per 1 per cent. of Na_2O added.
5	40	73
10	28	56
15	20	43
20	13	31
30	−5	−13
40	−2	−6

Comparison of the two Tables VIII. and IX. shows that the effect of PbO upon dispersion is much greater than the effect of an equivalent molecular amount of Na_2O.

It is to be noted that above 30 molecules of PbO the addition of Na_2O causes a fall in total dispersion.

Curves V and VI in Fig. 2 show the ν values of the glasses of the two series. It will be seen that the ν values are greater in the series containing the less Na_2O when corresponding glasses are compared. The ν values decrease continuously with increasing PbO content, that is, with increasing η_D.

A study of the partial dispersions $(\eta_D - \eta_C)$ and $(\eta_F - \eta_D)$ in both series shows that increasing the PbO in a glass lengthens both the red and the blue ends of the spectrum. From the rise in the β values with increase in PbO, it is evident that the blue end is spread relatively more than the red.

An examination of the values of the refractive index and total dispersion of the foregoing glasses proves that PbO plays by far the most important part in determining the values for each glass. Thus the values of η_D, C—F, and ν for both series are close together, showing that small additions of SiO_2 and Na_2O affect refractive index and total dispersion but slightly, whilst equally small additions of PbO cause large alterations in the values.

3. *Devitrification.*

(1) In cooling from 1350° to the ordinary temperature in twelve hours there were no signs of devitrification in any of the first series. In the second series, the first glass, $100SiO_2, 20Na_2O, 5PbO$, devitrified, a separation of silica taking place. The remainder of the glasses of this series were quite plain.

(2) A further test of devitrification was carried out, small pieces of each glass being kept for six hours at a temperature of 900°, and then slowly cooled for twelve hours to the ordinary temperature. The results are shown in Table X.

TABLE X.

Melt No.	Results.	
	Series $100SiO_2,40Na_2O,xPbO$.	
180 *A*	Quite melted.	Very slight surface film.
B	do.	Very slight surface film.
C	do.	No film. Quite clear.
D	do.	do.
E	do.	do.
F	do.	do.
	Series $100SiO_2,20Na_2O,xPbO$.	
181 *A*	Did not melt.	Total devitrification.
B	Just melted.	Thick devitrified surface layer.
C	Melted.	Slight edge film.
D	do.	No film. Quite clear.
E	do.	do.
F	do.	do.

In both series it will be seen that as the PbO increased, the tendency to devitrification became less. In the case of 180 *A* and 180 *B* the slight surface film was crystalline, and appeared as a surface deposit of feathery, branching crystals. When the SiO_2 was greater than 65 per cent., silica separated out under the above conditions. It is to be noted that glasses like 181 *F* containing 55 per cent. of PbO showed no tendency to deposit lead silicate.

4. *Solubility.*

Solubility tests as outlined previously * were carried out. Table XI contains the results of these tests. The numbers under the heading "H_2SO_4" represent the number of milligrams of H_2SO_4 required to neutralise the base dissolved out of 100 grams of powdered glass. Under the heading "Na_2O" the figures represent milligrams of Na_2O equivalent to this H_2SO_4 value. "Weight dissolved" is obtained by subtracting weight of undissolved matter from weight of original glass. This is an unsatisfactory figure, as insoluble compounds may be formed, due to reaction of the glass and the water, that is, "weight dissolved" may be too low.

TABLE XI.

	Series $100SiO_2,40Na_2O,xPbO$.				Series $100SiO_2,20Na_2O,xPbO$.		
	Milligrams per 100 grams of				Milligrams per 100 grams of		
Melt No.	Weight dissolved.	H_2SO_4.	Equiv. Na_2O.	Melt No.	Weight dissolved.	H_2SO_4.	Equiv. Na_2O.
180 *A*	39108	31569	19974	181 *A*	—	—	—
B	11000	9303	5886	*B*	672	691	437
C	1826	4160	2632	*C*	538	513	325
D	1800	3426	2167	*D*	296	369	233
E	1124	1678	1062	*E*	178	140	89
F	880	1042	660	*F*	128	91	58

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* This vol., TRANS., pp. 36, 37.

In the first series, the residue of the glass 180 *A*, after treatment with water, was gelatinous in parts, indicating that some reaction had taken place between the water and the powdered glass. Glasses 180 *B* and 180 *C* in the same series also showed the formation of this material, but not markedly. None of the other glasses exhibited this phenomenon. It would appear that this gelatinous material is only formed when the Na_2O content of a glass is greater than 20 per cent.

The following facts are emphasised from a study of the above table:—

(1) As the PbO content increases the solubility decreases.

(2) For equivalent PbO content the glass containing the least Na_2O is the least soluble.

(3) The value of PbO in rendering glass insoluble is strikingly shown in both series. Thus in the first series, comparing the glasses 180 *A* and 180 *D*, it will be seen that increasing the percentage lead oxide content three times diminishes the solubility number (as represented by the H_2SO_4) nine times.

(4) The results show the powerful effect of Na_2O in causing the solubility of a glass to be high. Thus glass 180 *C*, containing about 20 per cent. of Na_2O, is considerably more soluble than the glass 181 *B*, containing about 12·5 per cent., although the former contains 28 per cent. of PbO and the latter only 23·5 per cent.

5. *Durability.*

(1) The solubility numbers under the heading "Milligrams H_2SO_4 per 100 grams" in Table XI indicate that durability in these glasses increases with increasing PbO content, and in contrasting the two series, where the molecular PbO content is the same, the glass containing the greater amount of Na_2O is the less durable.

(2) Classifying the glasses under the standards of durability worked out previously,* it will be seen that none of the glasses in the first series could be used for optical purposes, as their durability is higher than Class V. In the second series, the classification is as under:—

Class I. $100SiO_2,20Na_2O,40PbO$.
I. $100SiO_2,20Na_2O,30PbO$.
II. $100SiO_2,20Na_2O,20PbO$.
III. $100SiO_2,20Na_2O,15PbO$.

Glass $100SiO_2,20Na_2O,10PbO$ is in Class IV for durability, but could not be made on a large scale on account of its tendency to devitrify.

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* This vol., TRANS., p. 39.

(3) The results predicted from the solubility values for durability are borne out by actual exposure tests, as is shown by Table XII.

TABLE XII.

Melt No.	Exposed for 100 hours to air saturated with moisture at 18°.	Exposed one year to ordinary atmospheric conditions (closed room).
	Series $100SiO_2,40Na_2O,xPbO$.	
180 *A*	Covered with greasy, liquid layer.	Greasy and covered with white crystals.
B	Covered with thin, greasy liquid.	Dulled over.
C	Covered with big spots of liquid.	,,
D	Blotched with liquid spots.	,,
E	Dry spots all over surface.	Dull all over and iridescent.
F	Slightly dulled all over.	,, ,,
	Series $100SiO_2,20Na_2O,xPbO$.	
181 *A*	—	—
B	A few liquid spots.	Faintly dulled.
C	Unaltered.	Very faintly dulled.
D	,,	,, ,,
E	,,	Bright.
F	,,	Bright, with signs of iridescence.

When glasses 180 *A*, *B*, *C*, *D* were cleaned and the superimposed liquid removed, they were found to be covered with iridescent markings. Comparison of the above results with Table II shows that only glasses with less than 12 per cent. of Na_2O remain unaltered after the one hundred hours' test, and only those with less than 8 per cent. of Na_2O retain their bright surface after exposure to air for one year. Even these have an iridescent sheen.

Summary and General Conclusions.

(1) Glasses of the two types $100SiO_2;40Na_2O,xPbO$ and
$100SiO_2,20Na_2O,xPbO$
have been investigated, where x lies between 5 molecules and 40 molecules. In a series, the molecular silica and sodium oxide contents remain the same, the only variant being the molecular PbO content.

(2) All the glasses can be founded at temperatures above 1350°, and exhibit corrosive action upon pot clay.

(3) The density of the glasses rises with increasing PbO content. Above 10 molecules of PbO, increasing the Na_2O decreases the density.

(4) The rate of increase in density per molecule of PbO falls as the PbO content rises.

(5) The refractive indices for the *C*, *D*, and *F* lines have been found. The refractive index increases with the addition of PbO, the rate of increase falling off as the molecular content of PbO increases. The rate of increase is greatest for the *F* line and least for the *C* line of the three lines measured.

(6) The refractive index increases as the density increases.

(7) Increasing the molecular PbO content increases the total dispersion, the blue portion of the spectrum being spread relatively more than the red.

(8) The ν values continually decrease as the η_D value rises.

(9) Glasses of the type specified above devitrify when the silica content is greater than 65 per cent. and deposit silica. Even when the PbO content is as high as 55 per cent. they show no tendency to deposit lead silicate.

(10) The solubility of the glasses in water decreases as the PbO or SiO_2 content rises, but increases rapidly as the Na_2O is increased.

(11) Glasses in the vicinity of $100SiO_2,20Na_2O,30PbO$ and $100SiO_2,20Na_2O,40PbO$ are of first-class durability and could be employed in the best optical constructions.

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XXVIII.—*The Development of Various Types of Glass. Part VII. The Interaction of Silica, Lead Oxide, and Potassium Oxide.*

By C. J. PEDDLE, D.Sc., F.I.C.

MANY of the better types of commercial glasses, in particular "cut glass" ware, are composed of silica, lead oxide, and potassium oxide, and the present paper deals with the interaction of these three oxides. Two series of melts were carried out, represented by the general molecular formulæ (1) $100SiO_2,40K_2O,x PbO$ and (2) $100SiO_2,20K_2O,x PbO$. They differ only from the series in the preceding paper in that K_2O is substituted molecularly for Na_2O. The "nucleus" of the glasses of the first series is 100 mols. of SiO_2, 40 mols. of K_2O, and of the second series 100 mols. of SiO_2, 20 mols. of K_2O, there being one variant oxide, namely, PbO.

The melting scheme in terms of molecular composition is shown below.

TABLE I.

Series $100SiO_2,40K_2O,xPbO$.				Series $100SiO_2,20K_2O,xPbO$.			
Melt No.	Mols. of SiO_2.	Mols. of K_2O.	Mols. of PbO.	Melt No.	Mols. of SiO_2.	Mols. of K_2O.	Mols. of PbO.
182 *A*	100	40	5	183 *A*	100	20	5
B	do.	do.	10	*B*	do.	do.	10
C	do.	do.	15	*C*	do.	do.	15
D	do.	do.	20	*D*	do.	do.	20
E	do.	do.	30	*E*	do.	do.	30
F	do.	do.	40	*F*	do.	do.	40

The batch compositions expressed in terms of percentage oxides are shown in Table II. For melting the glasses, sand, potassium carbonate, red lead oxide, and potassium nitrate were used, the last-named being introduced to prevent the deposition of metallic lead during melting (see this vol., Trans., p. 299).

TABLE II.

Calculated Percentage Batch Composition.

Series $100SiO_2,40K_2O,xPbO$.					Series $100SiO_2,20K_2O,xPbO$.				
No.	SiO_2.	K_2O.	PbO.	F_2O_3.	No.	SiO_2.	K_2O.	PbO.	Fe_2O_3.
182 *A*	55·07	34·45	10·20	0·28	183 *A*	66·55	20·81	12·31	0·33
B	49·98	31·27	18·50	0·25	*B*	59·25	18·52	21·94	0·29
C	45·75	28·62	25·40	0·23	*C*	53·40	16·69	29·65	0·26
D	42·18	26·38	31·23	0·21	*D*	48·60	15·20	35·97	0·23
E	36·49	22·81	40·52	0·18	*E*	41·18	12·88	45·74	0·20
F	32·15	20·10	47·60	0·15	*F*	35·74	11·18	52·91	0·17

Results.

(1) In the series of glasses Nos. 1 and 2, the first three melts were very effervescent, and only very small pieces of glass could be obtained. These quickly became slimy and covered with a white, opaque layer. In this series only the last three glasses could be employed to get trustworthy results in many of the tests.

(2) In both series the colour deepened as the PbO content increased, showing that increasing the PbO caused increased action on the pot. The glasses of the first series were more deeply coloured than those of the corresponding glasses in the second series. Thus glass 182 *A* was pale blue and 182 *F* deep bluish-green, the other glasses being intermediate in colour. In the second series the first four glasses were almost colourless, 183 *E* was faintly green, and 183 *F* greenish-yellow. From these results it will be seen that K_2O exercises a powerful corrosive action upon pot clay in the lead glasses.

(3) The glasses were very brilliant. Their brilliance was more marked and they were decidedly less coloured than the corresponding glasses of the soda series discussed in the preceding paper.

PROPERTIES OF THE GLASSES.

1. *Density.*

The following density results were obtained; the values for glasses 182 *A*, *B*, and *C* could not be obtained by experiment. The numbers (shown in parenthesis in the table) were extrapolated.

FIG. 1.

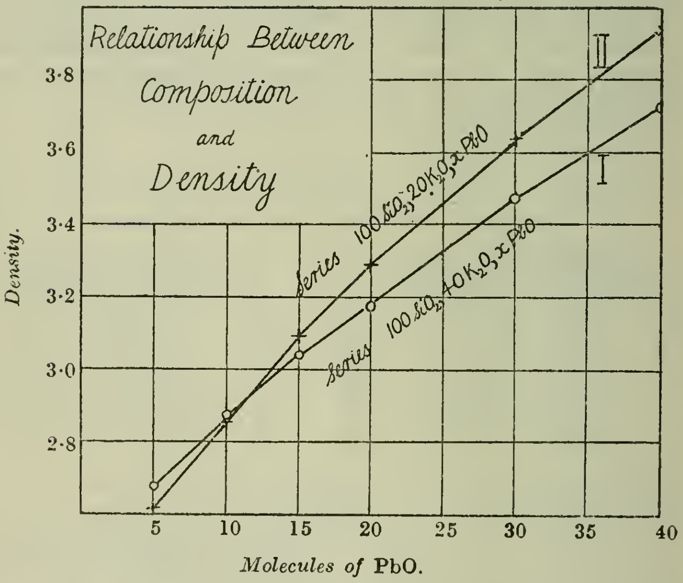


TABLE III.

Series $100SiO_2,40K_2O,xPbO$.

Melt No.	Density.
182 *A*	(2·681)
B	(2·868)
C	(3·043)
D	3·175
E	3·474
F	3·728

Series $100SiO_2,20K_2O,xPbO$.

Melt No.	Density.
183 *A*	2·616
B	2·849
C	3·089
D	3·290
E	3·640
F	3·942

A comparison of the two series is shown in Fig. 1, and the following conclusions are to be drawn from the results:—

(1) The density values increase as the molecular PbO content increases.

(2) In glasses containing more than 10 molecules of PbO the addition of K_2O decreases the density.

(3) The rate of increase in density per molecule of PbO added decreases as the PbO content rises.

(4) The rate of increase in density is greater in the series containing the less K_2O.

The following table shows the effect of PbO upon these glasses for different concentrations of lead oxide, the rises in density per molecule of PbO added and per 1 per cent. of PbO added being given side by side.

TABLE IV.

Series $100SiO_2,40K_2O,xPbO$.			Series $100SiO_2,20K_2O,xPbO$.		
Mols. PbO.	$10^4\times$ rise in density per mol. of PbO added.	$10^4\times$ rise in density per 1 p.c. of PbO added.	Mols. PbO.	$10^4\times$ rise in density per mol. of PbO added.	$10^4\times$ rise in density per 1 p.c. of PbO added.
5—10	(374)	(225)	5—10	466	242
10—15	(350)	(253)	10—15	480	311
15—20	(264)	(226)	15—20	402	318
20—30	299	321	20—30	350	352
30—40	254	356	30—40	302	421

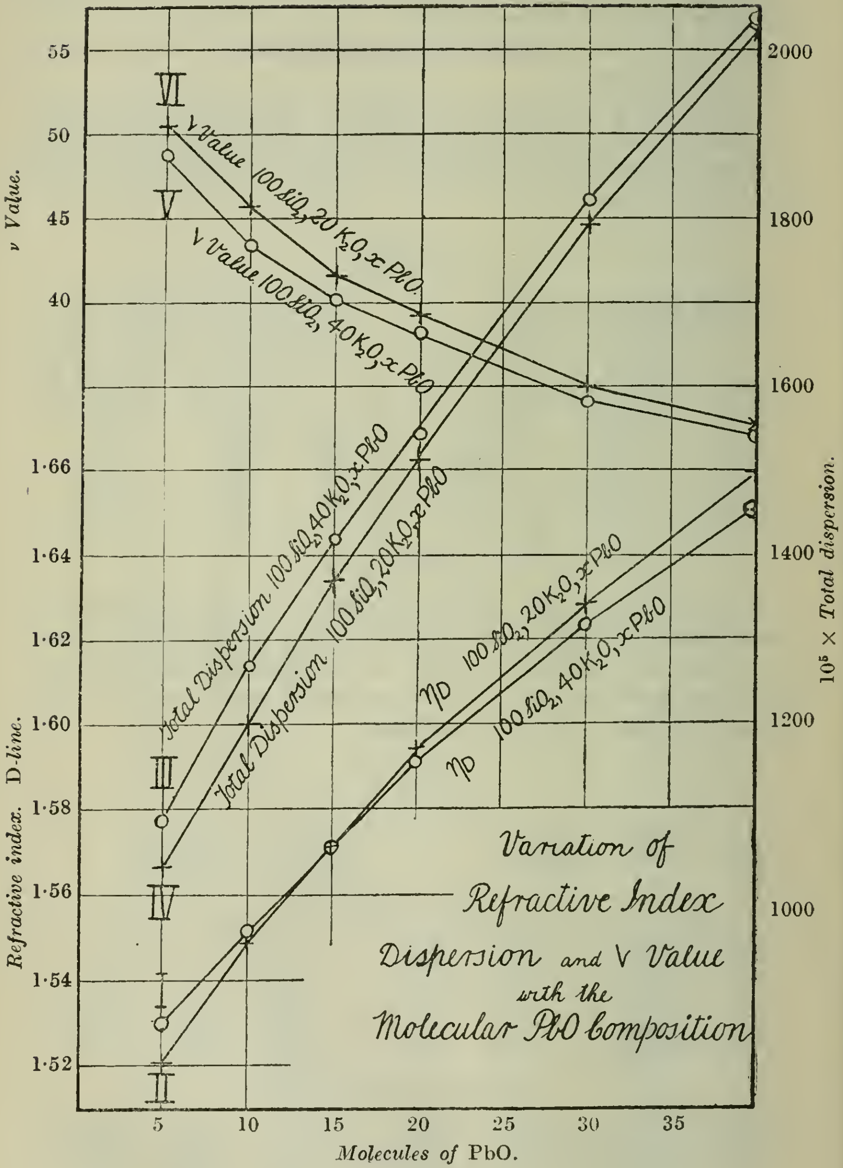
2. *Refractive Index.*

In the first series, the first three glasses were not obtainable in pieces large or durable enough to permit of trustworthy readings for refractive index to be taken on the Pulfrich refractometer. The values given in Table V for these glasses were therefore extrapolated, and are shown in parenthesis.

TABLE V.

Melt No.	Refractive index. η_D	Total dispersion $10^5\times\eta_F-\eta_C$.	ν.	Partial dispersion $10^5\times\eta_D-\eta_C$.	Partial dispersion $10^5\times\eta_F-\eta_D$.	β.
		Series $100SiO_2,40K_2O,xPbO$.				
182 *A*	(1·5290)	(1087)	(48·67)	—	—	—
B	(1·5510)	(1270)	(43·38)	—	—	—
C	(1·5710)	(1422)	(40·15)	—	—	—
D	1·5910	1543	38·30	443	1100	0·713
E	1·6230	1822	34·19	519	1303	0·715
F	1·6508	2037	31·95	555	1482	0·718
		Series $100SiO_2,20K_2O,xPbO$.				
183 *A*	1·5201	1029	50·53	300	729	0·709
B	1·5480	1200	45·67	348	852	0·710
C	1·5707	1372	41·59	396	976	0·711
D	1·5941	1514	39·24	436	1078	0·712
E	1·6284	1794	35·03	511	1283	0·715
F	1·6596	2022	32·62	585	1437	0·717

FIG. 2.


ν Value.
55
50
45
40
Refractive index. D-line.
1·66
1·64
1·62
1·60
1·58
1·56
1·54
1·52
10⁵ × Total dispersion.
2000
1800
1600
1400
1200
1000
VI
V
III
IV
II
ν Value 100 SiO₂, 20 K₂O, x PbO
ν Value 100 SiO₂, 40 K₂O, x PbO
Total Dispersion 100 SiO₂, 40 K₂O, x PbO
Total Dispersion 100 SiO₂, 20 K₂O, x PbO
ηD 100 SiO₂, 20 K₂O, x PbO
ηD 100 SiO₂, 40 K₂O, x PbO
Variation of
Refractive Index
Dispersion and V Value
with the
Molecular PbO Composition
5
10
15
20
25
30
35
Molecules of PbO.

A comparison of the two series is shown in Fig. 2. Curves I and II represent the variation in η_D for the two series.

The following remarks have to be made upon the optical constants of these two series of glasses:—

(1) In both series the refractive index increases with the molecular PbO content.

(2) The rate of increase of refractive index diminishes as the PbO content rises. This rate of increase is greater in the series containing the less K_2O.

(3) The addition of K_2O causes a decrease in the refractive index when the PbO content is more than 15 molecules.

(4) In potash–lead oxide–silica glasses of the type

$$100SiO_2,xK_2O,yPbO,$$

where x lies between 20 mols. and 40 mols. and y between 5 mols. and 40 mols., the greater the amount of K_2O in the glass the less is the effect of adding PbO. Also the greater the amount of PbO in the glass the less is the effect of adding K_2O.

This statement is probably true for all values of x and y capable of yielding glasses.

(5) The respective effects of PbO and of K_2O upon η_D for different concentrations of the two oxides are shown in Tables VI and VII. The rises in η_D per molecule and per 1 per cent. addition of PbO are shown side by side.

TABLE VI.

Rise in Refractive Index of *D* Line due to Addition of PbO.

Series $100SiO_2,40K_2O,xPbO$.			Series $100SiO_2,20K_2O,xPbO$.		
Mols. PbO.	$10^5 \times$ rise per mol. of PbO added.	$10^5 \times$ rise per 1 p.c. of PbO added.	Mols. PbO.	$10^5 \times$ rise per mol. of PbO added.	$10^5 \times$ rise per 1 p.c. of PbO added.
5—10	(440)	(265)	5—10	560	291
10—15	(400)	(290)	10—15	454	294
15—20	(400)	(343)	15—20	468	370
20—30	320	344	20—30	343	351
30—40	278	392	30—40	312	435

TABLE VII.

Rise in Refractive Index of *D* Line due to Addition of K_2O.

Mols. PbO.	$10^5 \times$ rise in η_D per mol. of K_2O added.	$10^5 \times$ rise in η_D per 1 p.c. of K_2O added.
5	45	66
10	15	23
15	1	3
20	−15	−28
30	−27	−54
40	−44	−99

Curves III and IV in Fig. 2 show the variation in total dispersion ($\eta_F - \eta_C$) in the two series with the increase in the number of PbO molecules. The following facts are of interest:—

(1) Total dispersion increases with increasing molecular PbO content.

(2) If the molecular PbO–SiO_2 contents of two glasses are the same, the glass containing the greater K_2O content will have the higher total dispersion.

(3) The rate of increase of total dispersion is slightly higher in the series containing the smaller K_2O, and falls away as the molecular PbO content increases.

(4) Table VIII shows how the total dispersion in the two series is affected by the addition (i) of a molecule of PbO, (ii) by 1 per cent. PbO. Table IX shows the effect of K_2O upon total dispersion at the various concentrations of PbO studied.

TABLE VIII.

Effect upon Total Dispersion by Addition of PbO.

Series $100SiO_2, 40K_2O, xPbO$.			Series $100SiO_2, 20K_2O, xPbO$.		
	$10^6 \times$ mean rise in total dispersion.			$10^6 \times$ mean rise in total dispersion.	
Mols. PbO.	Per mol. of PbO added.	Per 1 p.c. of PbO added.	Mols. PbO.	Per mol. of PbO added.	Per 1 p.c. of PbO added.
5—10	366	220	5—10	342	178
10—15	304	220	10—15	344	223
15—20	242	207	15—20	284	224
20—30	279	300	20—30	280	286
30—40	215	300	30—40	228	318

TABLE IX.

Effect on Total Dispersion caused by Addition of K_2O.

Mols. PbO.	$10^6 \times$ rise in total dispersion per mol. of K_2O added.	$10^6 \times$ rise in total dispersion per 1 p.c. of K_2O added.
5	29	44
10	35	54
15	25	42
20	15	26
30	14	28
40	8	16

Curves V and VI show the ν values of the glasses of the two series. The ν values are greater in the series containing the smaller molecular amount of K_2O. They continually decrease as the η_D value increases.

A study of the partial dispersions indicates that increasing the PbO lengthens both the red and blue ends of the spectrum. The blue end is lengthened relatively more than the red.

3. *Devitrification.*

(1) In cooling down from 1350° to the ordinary temperature in twelve hours there were no signs of devitrification in either series.

(2) A further test of devitrification was carried out as indicated in previous papers (this vol., p. 34), and the following results were obtained.

TABLE X.

Melt No.	Results.	
	Series $100SiO_2,40K_2O,xPbO$.	
182 *A*	Melted down fully.	Very bad skin.
B	do.	do.
C	do.	Bad skin.
D	do.	do.
E	do.	Fairly bad skin.
F	do.	do.
	Series $100SiO_2,20K_2O,xPbO$.	
183 *A*	Did not melt.	Very bad skin.
B	Just melted.	do.
C	do.	do.
D	Melted.	Rather bad skin.
E	do.	do.
F	do.	do.

None of the glasses showed devitrification, but all had a skin which improved as the PbO content was increased. The higher the K_2O content, the worse was the skin.

4. *Solubility.*

The solubility of the glasses was tested in the usual way. The first three glasses in the Series $100SiO_2,40K_2O,xPbO$ were not tested. Their solubility is very large. Even in glass 182 *C*, containing 15 mols. of PbO, more than half the powdered glass is soluble. The results are expressed as in previous papers.

TABLE XI.

	Series $100SiO_2,40K_2O,xPbO$. Milligrams per 100 grams.				Series $100SiO_2,20K_2O,xPbO$. Milligrams per 100 grams.		
Melt No.	Weight dissolved.	H_2SO_4.	K_2O.	Melt No.	Weight dissolved.	H_2SO_4.	K_2O.
182 *A*	—	—	—	183 *A*	17,548	9618	9255
B	—	—	—	*B*	3178	3714	3574
C	—	—	—	*C*	1926	1608	1547
D	42,338	23,019	21,180	*D*	764	601	578
E	8708	18,974	18,263	*E*	678	258	249
F	4140	8935	8598	*F*	376	154	148

(1) In both series the solubility falls as the PbO content increases.

(2) For equivalent molecular PbO content the glass containing the smaller K_2O is the less soluble.

(3) The value of PbO in rendering a glass insoluble is again emphasised, as is the powerful effect of K_2O in causing solubility.

(4) In every glass of the first series and in the first glass of the second series a gelatinous substance is formed on heating the powdered glasses with water. All the glasses giving this gelatinous material contain more than 20 per cent. of K_2O and have a solubility value greater than 9000 (that is, H_2SO_4 value). From this gelatinous material formation may be deduced the fact that interaction has taken place between the glasses and the water. Thus values under the heading "Weight dissolved" are not to be relied upon.

5. *Durability.*

(1) The solubility numbers in Table XI prove that the durability of these glasses increases as the PbO content rises. Also it will be seen that the higher the K_2O content the less durable the glass. Classifying the glasses under the standards of durability worked out previously (this vol., Trans., p. 39), none of the glasses in the first series could be used for optical instruments. In the second series, Glass $100SiO_2,20K_2O,20PbO$ is in Class IV, Glass $100SiO_2,20K_2O,30PbO$ is in Class II, and $100SiO_2,20K_2O,40PbO$ is in Class I.

(2) The exposure test results for durability are given in Table XII below, and confirm those of the solubility tests.

TABLE XII.

Melt No.	Exposed 100 hours to air saturated with H_2O at 18°.	Exposed one year to ordinary atmospheric conditions (closed room).
	Series $100SiO_2,40K_2O,xPbO$.	
182 *A*	Covered with milky, white slime.	Thick, hard, white, opaque skin.
B	do.	do.
C	Covered with thick film of liquid.	do.
D	Covered with distinct film of liquid.	do.
E	Covered with thin liquid layer.	Thin, white, opaque skin.
F	Iridescent, dry, big spots.	White, semi-opaque skin.
	Series $100SiO_2,20K_2O,xPbO$.	
183 *A*	Spotted all over surface.	Badly dulled.
B	Slightly spotted.	do.
C	do.	do.
D	Odd spots here and there.	do.
E	Unaltered.	do. Iridescent.
F	do.	do. do.

It will be noted that all the glasses containing more than 15 per cent. of K_2O were affected by the one hundred hours' test.

Summary and General Conclusions.

(1) Glasses of the two types $100SiO_2,40K_2O,xPbO$ and $100SiO_2,20K_2O,xPbO$ have been investigated, where x lies between 5 molecules and 40 molecules. In a series the molecular silica and potassium oxide contents remain the same, the only variant being the molecular PbO content.

(2) All the glasses can be founded at temperatures above 1350° and exhibit corrosive action upon pot clay.

(3) The density of the glasses increases as the PbO content rises.

(4) The rate of increase of density diminishes as the PbO increases.

(5) The refractive indices for the C, D, and F lines have been determined. The refractive index increases with the addition of PbO, the rate of increase falling off as the PbO increases. The rate of increase is greatest for the F line and least for the C line of the three lines investigated.

(6) Refractive index increases as the density increases.

(7) Increasing the molecular PbO content increases the total dispersion, the blue end of the spectrum being spread relatively more than the red.

(8) The ν values decrease continuously as the η_D increases.

(9) None of the glasses devitrify, but all film badly on prolonged heating at 900°.

(10) The solubility of the glasses decreases as the amount of PbO increases, but increases rapidly as the K_2O content is increased.

(11) All the glasses of the first-named series are of very poor durability. Glass $100SiO_2,20K_2O,40PbO$ is of first-class durability and very suitable for optical work. This glass is not far removed in optical constants from the Schott glass O. 102. (see Part IX, p. 366).

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XXIX.—*The Development of Various Types of Glass. Part VIII. The Interaction of Silica, Lead Oxide, and the Oxides of Sodium and Potassium.*

By C. J. Peddle, D.Sc., F.I.C.

The two preceding papers dealt with the interaction of silica and lead oxide, first with sodium oxide and secondly with potassium oxide. The present paper deals with glasses containing both the alkaline oxides in conjunction with lead oxide and silica. Thus the "nucleus" in Series I is 100 mols. of SiO_2, 20 mols. of Na_2O, 20 mols. of K_2O, and in Series II 100 mols. of SiO_2, 10 mols. of Na_2O, 10 mols. of K_2O, the variant oxide being PbO in each series. The actual composition of the glasses investigated was as follows.

Table I.

Molecular Composition.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.					Series $100SiO_2,10Na_2O,10K_2O,xPbO$.				
Melt No.	Mols. of SiO_2.	Mols. of Na_2O.	Mols. of K_2O.	Mols. of PbO.	Melt No.	Mols. of SiO_2.	Mols. of Na_2O.	Mols. of K_2O.	Mols. of PbO.
184 *A*	100	20	20	5	185 *A*	100	10	10	5
B	do.	do.	do.	10	*B*	do.	do.	do.	10
C	do.	do.	do.	15	*C*	do.	do.	do.	15
D	do.	do.	do.	20	*D*	do.	do.	do.	20
E	do.	do.	do.	30	*E*	do.	do.	do.	30
F	do.	do.	do.	40	*F*	do.	do.	do.	40

Table II gives the batch compositions expressed in terms of the percentage oxides. The same materials were used in making up the batches as in previous investigations, some nitrate being incorporated in the batch to prevent deposition of metallic lead.

Table II.

Percentage Composition.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.

Melt No.	SiO_2.	Na_2O.	K_2O.	PbO.	Al_2O_3 + Fe_2O_3.
184 *A*	58·55	12·03	18·30	10·83	0·29
B	52·81	10·86	16·51	19·56	0·26
C	48·12	9·88	15·03	26·72	0·24
D	44·18	9·08	13·81	32·71	0·22
E	37·96	7·81	11·88	42·16	0·19
F	33·30	6·83	10·40	49·30	0·17

TABLE II.—*cont.*

Percentage Composition.

Series $100SiO_2,10Na_2O,10K_2O,xPbO$.

Melt No.	SiO_2.	Na_2O.	K_2O.	PbO.	Al_2O_3 + Fe_2O_3.
185 *A*	69·01	7·10	10·78	12·77	0·34
B	61·19	6·29	9·56	22·66	0·30
C	54·95	5·65	8·59	30·54	0·27
D	49·89	5·13	7·80	36·93	0·25
E	42·11	4·33	6·59	46·76	0·21
F	36·43	3·74	5·70	53·95	0·18

Results.

(1) Melts of the first series were effervescent, particularly the first two. Only small pieces of glass were available. Repeated melts, in which the batch was added in smaller quantities over a longer filling-on period, did not improve matters.

(2) In Series II, melt 185 *A* only partially fluxed.

(3) The colour deepened in both series as the lead oxide percentage increased. The glasses of the first series were more coloured than those of the second series, proving the corrosive action of alkali.

(4) The glasses of the second series, containing less alkali, were more difficult to stir, and were more striated than those of the first series.

(5) The glasses were intermediate in colour and brilliance between the corresponding glasses of the Na_2O and K_2O series.

(6) The glasses of the first series varied from light blue in 184 *A* to deep green in 184 *F*. In the second series, the first two glasses were almost colourless. The remaining glasses gradually deepened in colour to a yellow glass in 185 *F*. This yellow was the characteristic yellow colour of glasses made with a high lead oxide percentage.

PROPERTIES OF THE GLASSES.

1. *Density.*

In the following table, which gives the density values, the numbers for 184 *A* and 185 *A* were extrapolated. The other values were obtained by the usual method.

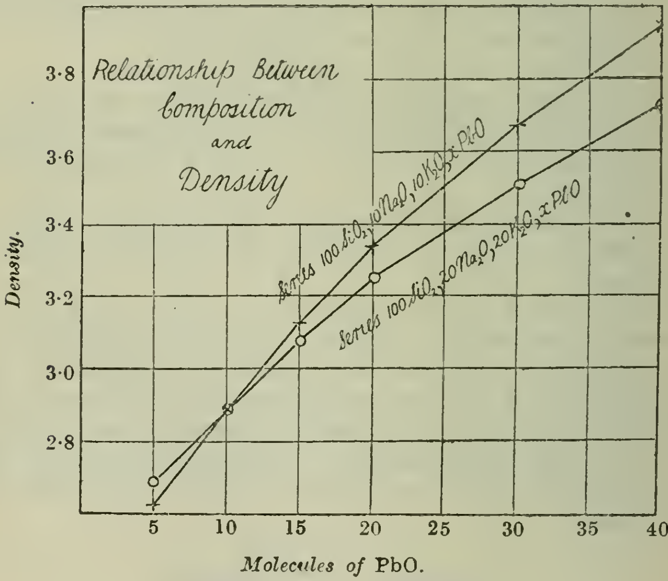
TABLE III.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.		Series $100SiO_2,10Na_2O,10K_2O,xPbO$.	
Melt No.	Density.	Melt No.	Density.
184 *A*	(2·690)	185 *A*	(2·623)
B	2·888	*B*	2·884
C	3·080	*C*	3·126
D	3·248	*D*	3·339
E	3·507	*E*	3·676
F	3·731	*F*	3·952

A comparison of the two series is shown in Fig. 1, and the following points require notice:—

(1) As the PbO content increases the density rises.

FIG. 1.



(2) In glasses containing more than 10 mols. of PbO, increasing the alkali content lowers the density.

(3) The rate of increase of density per mol. of PbO added is greater in the series containing the smaller alkali content, and it decreases with increase in PbO.

(4) Table IV shows the effect upon the glasses of the addition of PbO at various concentrations of PbO.

TABLE IV.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.			Series $100SiO_2,10Na_2O,10K_2O,xPbO$.		
	10^4 × rise in density per			10^4 × rise in density per	
Mols. of PbO.	Mol. of PbO added.	1 per cent. of PbO added.	Mols. of PbO.	Mol. of PbO added.	1 per cent. of PbO added.
5—10	396	227	5—10	522	264
10—15	384	268	10—15	482	307
15—20	336	280	15—20	426	333
20—30	259	261	20—30	337	343
30—40	224	313	30—40	276	384

2. *Refractive Index.*

All the meltings, with the exception of 185 *A*, yielded pieces large enough to provide cubes for the Pulfrich refractometer. The values for 185 *A* in Table V below are extrapolated.

TABLE V.

Melt No.	Refractive index. η_D	10^5 × total disp. $=10^5(\eta_F-\eta_C)$.	ν.	10^5 × part. disp. $=10^5(\eta_D-\eta_C)$.	10^5 × part. disp. $=10^5(\eta_F-\eta_D)$.	β.
		Series $100SiO_2,20Na_2O,20K_2O,xPbO$.				
184 *A*	1·5331	1078	49·45	313	765	0·710
B	1·5562	1260	44·14	364	896	0·711
C	1·5773	1411	40·91	406	1005	0·712
D	1·5947	1550	38·37	445	1105	0·713
E	1·6226	1808	34·43	515	1293	0·715
F	1·6509	2029	32·29	574	1455	0·717
		Series $100SiO_2,10Na_2O,10K_2O,xPbO$.				
185 *A*	(1·5180)	1018	50·88	296	722	0·709
B	1·5453	1198	45·52	347	851	0·710
C	1·5692	1362	41·79	394	968	0·711
D	1·5933	1503	39·47	433	1070	0·712
E	1·6280	1781	35·26	509	1272	0·714
F	1·6571	2006	32·75	570	1436	0·716

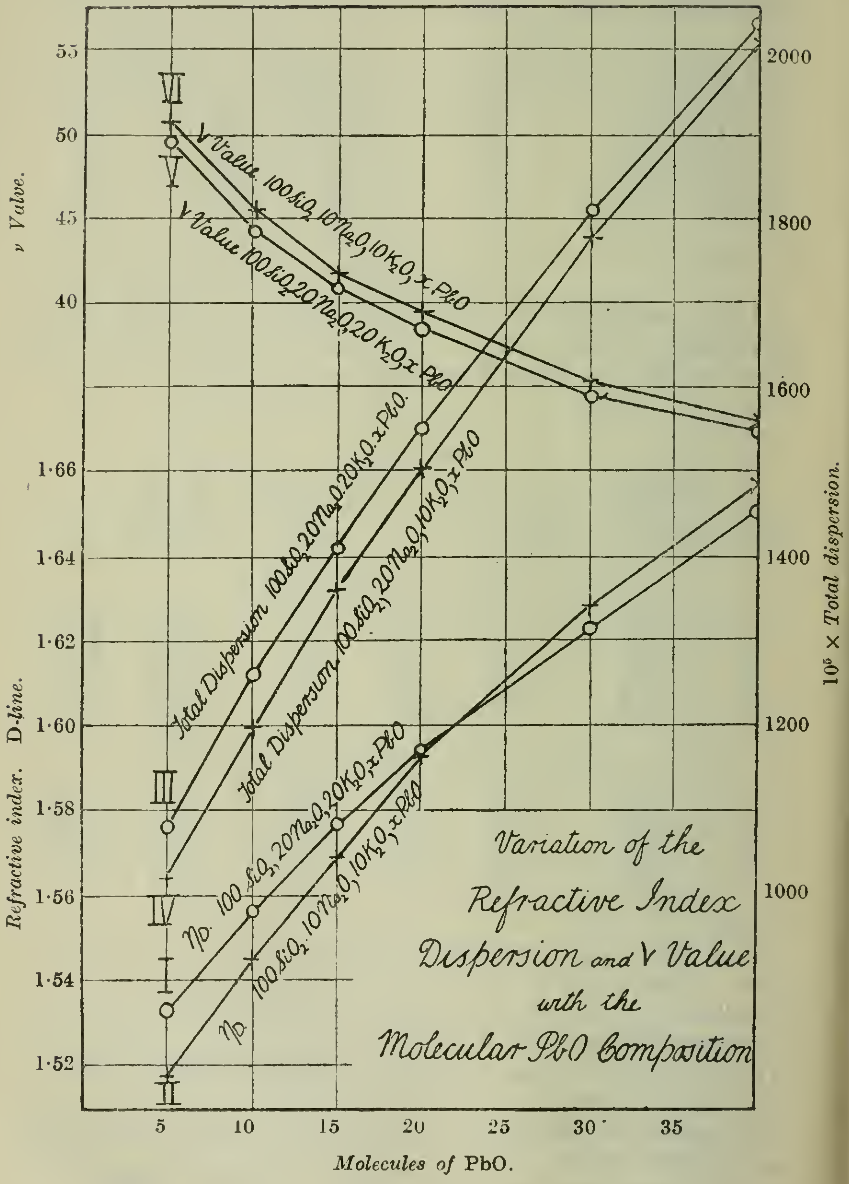
Fig. 2 shows diagrammatically the results for both of the above series. Curves I and II show the variation in η_D in the two series as the PbO content becomes greater. The following facts are to be commented on:—

(1) The refractive index increases in both series as the molecular PbO content increases.

(2) The rate of increase is greater in the series containing the smaller alkali content.

(3) In glasses containing more than 23 molecules of PbO, the addition of Na_2O,K_2O decreases the refractive index.

FIG. 2.


55
50
45
40
ν Value.
1·66
1·64
1·62
1·60
1·58
1·56
1·54
1·52
Refractive index. D-line.
2000
1800
1600
1400
1200
1000
10^5 × Total dispersion.
5
10
15
20
25
30
35
Molecules of PbO.
VI
V
III
IV
I
II
ν Value 100 SiO₂ 10 Na₂O, 10 K₂O, x PbO
ν Value 100 SiO₂ 20 Na₂O, 20 K₂O, x PbO
Total Dispersion 100 SiO₂ 20 Na₂O. 20 K₂O. x PbO.
Total Dispersion 100 SiO₂, 20 Na₂O, 10 K₂O, x PbO
η_D 100 SiO₂, 20 Na₂O, 20 K₂O, x PbO
η_D 100 SiO₂, 10 Na₂O, 10 K₂O, x PbO
Variation of the
Refractive Index
Dispersion and ν Value
with the
Molecular PbO Composition

(4) In alkali–lead oxide–silica glasses of the type

$$100SiO_2,xNa_2O,xK_2O,yPbO,$$

where x lies between 10 molecules and 20 molecules and y between 5 molecules and 40 molecules, the greater the amount of lead oxide in the glass the less will be the effect of adding alkali. Again, the greater the amount of alkali in the glass the less will be the effect of the addition of PbO.

This statement is probably true for all values of x and y capable of yielding glasses.

(5) The respective effects of PbO and Na_2O,K_2O upon the refractive index of the D line at varying concentrations of PbO and alkali are shown in Table VI and Table VII. The rises in η_D per molecule and per 1 per cent. addition of PbO and alkali are shown side by side.

TABLE VI.

Rise in η_D Due to Addition of PbO.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.			Series $100SiO_2,10Na_2O,10K_2O,xPbO$.		
Mols. of PbO.	$10^5 \times$ rise per mol. of PbO.	$10^5 \times$ rise per 1 p.c. of PbO.	Mols. of PbO.	$10^5 \times$ rise per mol. of PbO.	$10^5 \times$ rise per 1 p.c. of PbO.
5—10	462	264	5—10	546	271
10—15	422	294	10—15	478	303
15—20	348	290	15—20	482	377
20—30	279	295	20—30	347	353
30—40	283	396	30—40	291	404

TABLE VII.

Rise in η_D Due to Addition of Na_2O,K_2O.

Mols. of PbO.	$10^5 \times$ rise in refractive index of D line per mol. of Na_2O,K_2O added.	$10^5 \times$ rise in refractive index per 1 p.c. of Na_2O,K_2O added.
5	75	121
10	55	90
15	41	76
20	7	14
30	-27	-61
40	-31	-79

Curves III and IV on Fig. 2 show the variation in total dispersion $(\eta_F - \eta_C)$ in the two series with increase in PbO molecules. The following facts should be observed:—

(1) As the molecular PbO content increases the total dispersion increases.

(2) If the molecular $PbO–SiO_2$ contents of two glasses are the

same, the glass containing the smaller amount of alkali will have the lower total dispersion.

(3) Table VIII shows how the total dispersion in the two series is affected by the addition (i) of a molecule of PbO, (ii) 1 per cent. of PbO. Table IX shows the effect of Na_2O,K_2O per molecule and per 1 per cent. addition upon total dispersion at the given PbO concentrations.

Table VIII.

Effect upon Total Dispersion of the Addition of PbO.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.			Series $100SiO_2,10Na_2O,10K_2O,xPbO$.		
	10^5 × mean rise in total dispersion.			10^5 × mean rise in total dispersion.	
Mols. of PbO.	Per mol. of PbO added.	Per 1 p.c. of PbO added.	Mols. of PbO.	Per mol. of PbO added.	Per 1 p.c. of PbO added.
5—10	364	208	5—10	360	182
10—15	302	211	10—15	328	209
15—30	278	232	15—20	282	221
30—40	258	273	20—30	278	282
40—50	221	309	30—40	225	313

Table IX.

Effect upon Total Dispersion Due to the Addition of Na_2O,K_2O.

Mols. of PbO.	10^5 × rise in total dispersion per mol. of Na_2O,K_2O added.	10^5 × rise in total dispersion per 1 p.c. of Na_2O,K_2O added.
5	30	48
10	31	54
15	25	46
20	24	46
30	14	31
40	12	29

Curves V and VI show the ν values of the glasses of the two series. It will be seen that these ν values are greater in the series containing the smaller amount of Na_2O,K_2O. They continually decrease as the value of η_D increases.

A study of the partial dispersions indicates that increasing the PbO lengthens both the red and blue ends of the spectrum, the blue being lengthened relatively more than the red.

3. *Devitrification.*

(1) In cooling down the melts to laboratory temperature in twelve hours there were no signs of devitrification in the first series. In the second series the glass $100SiO_2,10Na_2O,10K_2O,5PbO$ contained deposited silica, but none of the rest of the glasses showed any signs of devitrification.

(2) The usual test of devitrification as outlined in previous papers gave the following results.

TABLE X.

Melt No.	Results.	
	Series $100SiO_2,20Na_2O,20K_2O,xPbO$.	
184 *A*	Melted.	Skin, very marked indeed.
B	do.	do. very marked.
C	do.	do. marked.
D	do.	do. do.
E	do.	do. slight.
F	do.	No surface film.
185 *A*	Not melted.	Total silica devitrification.
B	Just melted.	Slight silica devitrification.
C	do.	Skin formed.
D	do.	do.
E	Melted.	No film.
F	do.	do.

In the first series all the glasses except 184 *F* film badly under the devitrification test. This film is worst in glass 184 *A*, and gradually disappears with increasing PbO content. It is markedly crystalline, and seems to be due to the high Na_2O,K_2O content of the glasses. When this is lower than about 20 per cent. in the first series the film disappears.

It will be noted that when the silica content is greater than 60 per cent., there is a separation of the silica under the test.

4. *Solubility.*

The usual test of the solubility of the powdered glasses was carried out. In Table XI the values under the heading "H_2SO_4" represent the number of milligrams of H_2SO_4 required to neutralise the base dissolved out of 100 grams of glass.

Under the heading "Na_2O,K_2O" the figures represent milligrams of alkaline oxide equivalent to this H_2SO_4 value, assuming that the oxides of sodium and potassium are dissolved out in the ratio of their molecular weights.

TABLE XI.

Series $100SiO_2,20Na_2O,20K_2O,xPbO$.				Series $100SiO_2,10Na_2O,10K_2O,xPbO$.			
	Milligrams per 100 grams.				Milligrams per 100 grams.		
Melt No.	Weight dissolved.	H_2SO_4.	Equivalent. Na_2O,K_2O	Melt No.	Weight dissolved.	H_2SO_4.	Equivalent Na_2O,K_2O.
184 *A*	65,052	31,212	25,976	185 *A*	2500	3321	2763
B	29,474	18,994	15,792	*B*	1902	1149	955
C	26,614	18,161	15,104	*C*	1068	677	563
D	3872	6585	5476	*D*	988	368	306
E	1546	3228	2685	*E*	660	161	140
F	1306	1495	1243	*F*	236	119	99

(1) In the first series it will be seen that more than half of the powdered glass $100SiO_2,20Na_2O,20K_2O,5PbO$ is soluble in water, and more than a quarter of the two glasses

$100SiO_2,20Na_2O,20K_2O,10PbO$

and $100SiO_2,20Na_2O,20K_2O,15PbO$. Then there appears a sudden diminution in solubility.

(2) Increasing the molecular PbO content decreases the solubility in both series.

(3) In two glasses of identical molecular PbO,SiO_2 content, the one containing the less alkali will be the less soluble.

(4) The value of PbO in rendering a glass insoluble is well brought out, as is also the powerful effect of alkali in causing solubility.

(5) In the first series a gelatinous material was formed on boiling the first four glasses, the amount decreasing as the PbO content increases. When the total alkali content was less than 20 per cent. this substance did not form. In the second series, where the alkali content was always less than 20 per cent., no gelatinous substance was found. The formation of this gelatinous matter points to reaction between the powdered glasses and the water. Thus the values under "Weight dissolved" in Table XI are untrustworthy, especially so in Series I.

5. *Durability.*

(1) The solubility numbers under the heading "Milligrams H_2SO_4 per 100 grams" in Table XI indicate that in both series the durability of these glasses increases with increasing PbO content. Contrasting the two series, it will be seen that in corresponding glasses where the molecular PbO and SiO_2 contents are the same, the glass containing the greater amount of alkali is the less durable.

(2) Classifying the glasses under the standards of durability worked out previously (this vol., Trans., p. 39), it will be noted that the two glasses $100SiO_2,10Na_2O,10K_2O,30PbO$ and

$100SiO_2,10Na_2O,10K_2O,40PbO$

are in Class I, the glass $100SiO_2,10Na_2O,10K_2O,20PbO$ is in Class II, and glass $100SiO_2,10Na_2O,10K_2O,15PbO$ is in Class III.

(3) The results predicted from the solubility tests are borne out by the exposure tests, as shown in Table XII. It will be observed from a comparison of this table with Table II that when the alkali content of any of these glasses is less than 16 per cent., no effect on the glass surface is to be seen after the exposure for one hundred hours to a moist atmosphere at 18°.

TABLE XII.

Melt No.	Exposed 100 hours to moist air at 18°.	Exposed one year to ordinary atmospheric conditions (closed room).
	Series $100SiO_2,20Na_2O,20K_2O,xPbO$.	
184 *A*	Covered with large patches of liquid.	Badly dulled
B	Like *A*, but less pronounced.	do. (better than *A*).
C	Like *B*, but less pronounced.	do. (better than *B*).
D	Like *C*, but less pronounced.	do. (better than *C*).
E	A few wet patches here and there.	do. (better than *D*).
F	A few faint wet patches.	Badly dulled and iridescent.
	Series $100SiO_2,10Na_2O,10K_2O,xPbO$.	
185 *A*	Very slight dulling effect.	Very faintly dulled.
B	No effect.	do.
C	do.	do.
D	do.	do.
E	do.	Bright.
F	do.	Bright and signs of iridescence.

Summary and General Conclusions.

(1) Glasses of the two types $100SiO_2,20Na_2O,20K_2O,xPbO$ and $100SiO_2,10Na_2O,10K_2O,xPbO$ have been investigated, where x lies between 5 molecules and 40 molecules. In each series it will be seen that the molecular SiO_2 and Na_2O,K_2O contents remain the same, only the PbO altering.

(2) All the glasses can be founded at temperatures above 1350° and exhibit corrosive action upon pot clay.

(3) The density of the glasses increases with an increase in the PbO content.

(4) Above a molecular PbO content of 10 molecules, the addition of alkali causes the density to fall.

(5) As the amount of PbO increases, the rate of increase of density per molecule of PbO added diminishes.

(6) The refractive indices for the *C*, *D*, and *F* lines of the spectrum have been found. The refractive index increases with the addition of PbO, the rate of increase falling away as the molecular PbO content becomes greater. The rate of increase is greatest for the *F* line and least for the *C* line of the three lines measured.

(7) The refractive index increases as the density increases.

(8) Increasing the molecular PbO content increases the total dispersion, the blue portion of the spectrum being spread relatively more than the red.

(9) The ν values decrease with increasing PbO content.

(10) As the η_D becomes greater the ν value becomes less.

(11) Glasses of the two types specified above show signs of devitrification when the silica percentage is greater than 61 per

cent. Under certain conditions they deposit silica. No signs of any lead silicate separation were observed, even in glasses containing 54 per cent. of PbO.

(12) The solubility of the glasses increases as the PbO content becomes greater, but rises rapidly when the alkali content is increased.

(13) Glasses in the vicinity of $100SiO_2,10Na_2O,10K_2O,30PbO$ and $100SiO_2,10Na_2O,10K_2O,40PbO$ could be used in the best optical work, as they are of first-class durability.

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MESSRS. WOOD BROS. GLASS CO., LTD.
BARNSLEY.

THE RESEARCH DEPT.,
DERBY CROWN GLASS CO., LTD
DERBY.

XXX.—*The Development of Various Types of Glass. Part IX. A Comparison of the Soda–Lead Oxide–Silica and the Potash–Lead Oxide–Silica Glasses.*

By C. J. PEDDLE, D.Sc., F.I.C.

THE general molecular formula $100SiO_2,xR_2O,yPbO$ represents the glasses of the types described in this paper, R_2O being the oxide of sodium, the oxide of potassium, or mixtures of the two oxides. The present paper correlates the results obtained in the three previous papers. The effect of the replacement of one alkaline oxide by the other, either wholly or in part, is discussed from the point of view of various important properties, first from the standpoint of molecular substitution and then from that of percentage substitution by weight. As was previously pointed out,* the investigation of glass problems is facilitated by following the lines of molecular constitution, but this should be augmented wherever possible by a parallel study along the lines of percentage composition. The "dual" method of attack is especially useful when dealing with the comparison of the effect of the substitution of one oxide by another, and this "dual" method is employed in this paper.

In order to study the properties of glasses of the above types from the point of view of percentage composition by weight, a number of additional meltings were carried out. Series 186 were soda glasses; series 187, potash glasses; and series 188 contained both soda and potash. The meltings were arranged in six sets, containing respectively 70, 65, 60, 50, 40, and 30 per cent. of silica. Each set was subdivided into sections according to the percentage of alkali oxide contained in it. Section *a* contained 25 per cent.; section *b*, 20 per cent.; section *c*, 15 per cent.; and section *d*, 10 per cent. The melting scheme is shown in Table I, together with remarks on the glasses. All the mixtures used, on cooling in the furnace after melting to the ordinary temperature, gave glasses except 186 *D* (SiO_2, 70; Na_2O, 10; PbO, 20 per cent.), 186 *G* (SiO_2, 65; Na_2O, 10; PbO, 25), and 187 *D* (SiO_2, 70; K_2O, 10; PbO, 20). These three mixtures gave glass on melting, and proofs from them

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* This vol. TRANS., p. 71.

TABLE I.

		Melt	Percentage				
Set.	Section.	No.	SiO_2.	PbO.	Na_2O.	K_2O.	Remarks.
I.	*a*	186*A*	70	5	25	—	Faint blue, bubbly
		187*A*	70	5	—	25	Colourless
	b	186*B*	70	10	20	—	Blue
		188*B*	70	10	10	10	Nearly colourless
		187*B*	70	10	—	20	Colourless
	c	186*C*	70	15	15	—	Deep blue
		187*C*	70	15	—	15	Colourless
	d	186*D*	70	20	10	—	White porcelain mass
		187*D*	70	20	—	10	Devitrified
II.	*b*	186*E*	65	15	20	—	Faint blue
		188*E*	65	15	10	10	Nearly colourless
		187*E*	65	15	—	20	Very slight blue tinge
	c	186*F*	65	20	15	—	Blue
		187*F*	65	20	—	15	Very slight
	d	186*G*	65	25	10	—	Devitrified (silica)
		187*G*	65	25	—	10	Colourless
III.	*a*	186*H*	60	15	25	—	Pale blue
		187*H*	60	15	—	25	Colourless
	b	186*J*	60	20	20	—	Faint blue
		188*J*	60	20	10	10	Nearly colourless
		187*J*	60	20	—	20	Colourless
	c	186*K*	60	25	15	—	Very faint blue
		187*K*	60	25	—	15	Colourless
	d	186*L*	60	30	10	—	Very faint greenish-blue
		187*L*	60	30	—	10	Colourless
IV.	*b*	186*M*	50	30	20	—	Pale green
		188*M*	50	30	10	10	Very slight blue
		187*M*	50	30	—	20	Very pale blue
	c	186*N*	50	35	15	—	Blue green
		187*N*	50	35	—	15	Colourless
	d	186*P*	50	40	10	—	Light green
		187*P*	50	40	—	10	Very light blue
V.	*b*	186*Q*	40	40	20	—	Green
		188*Q*	40	40	10	10	Nearly colourless
		187*Q*	40	40	—	20	Colourless
	c	186*R*	40	45	15	—	Light green
		187*R*	40	45	—	15	Colourless
	d	186*S*	40	50	10	—	Yellow green
		187*S*	40	50	—	10	Colourless
VI.	*b*	186*T*	30	50	20	—	Green like *Q*
		188*T*	30	50	10	10	Green
		187*T*	30	50	—	20	Green

remained as glasses on rapidly cooling, but on slower cooling in the pots they devitrified. 186 *D* gave a white, porcelain-like mass with slight signs of glass, whilst 186 *G* and 187 *D* gave a white mass at the top of the melt, and glass, interspersed with silica separations, beneath. It will be noted that in every case the potash glass had a better colour than the corresponding soda glass. Also, the colour of the glasses improved as the alkali content decreased.

Properties of the Glasses.

1. *Density.*

A comparison of the densities from the molecular point of view of the glasses of type $100SiO_2,40R_2O,xPbO$ is given in Fig. 1. It will be noted that the soda glass in each case has a density higher than its corresponding potash glass, and the glass with mixed alkalis is intermediate.

FIG. 1.

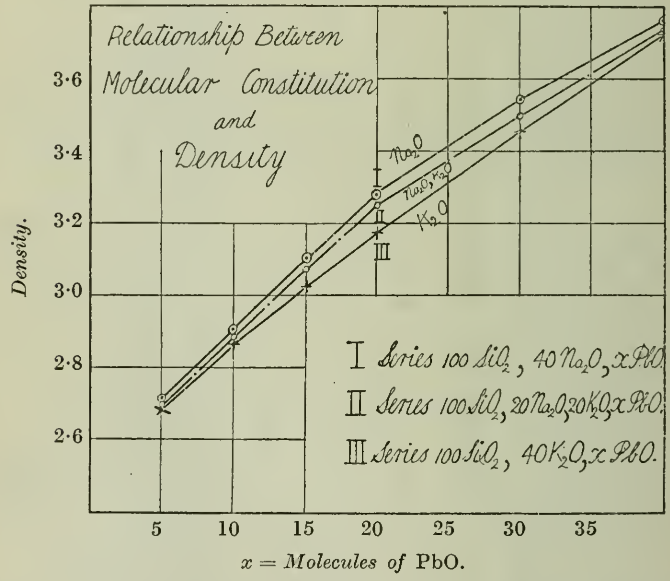


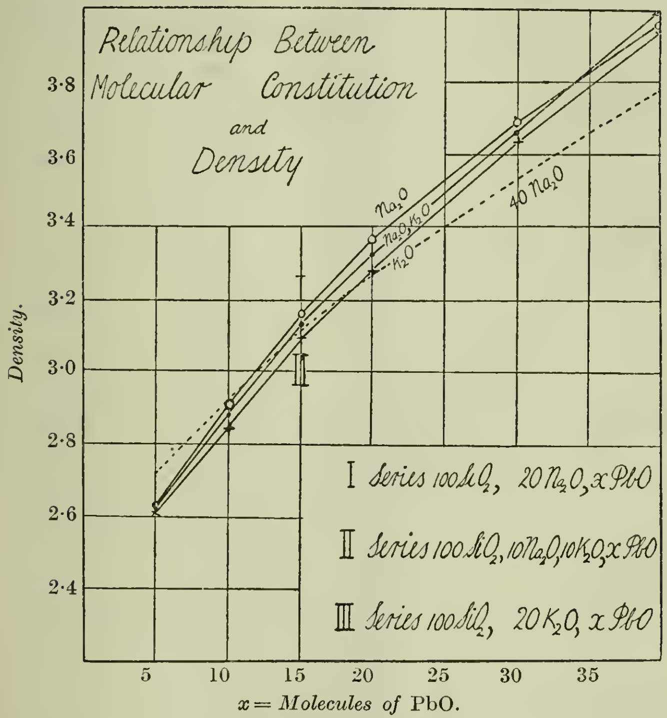
Fig. 2 shows the densities of the glasses $100SiO_2,20R_2O,xPbO$. Here, again, the soda glasses have a higher density than the corresponding potash glasses when the PbO content is greater than 3·5 mols. The mixed alkaline oxide glasses are intermediate.

(1) Both series of curves emphasise the fact that lead oxide exerts a preponderating effect upon density, which increases with increase in the molecular lead oxide content.

(2) The glasses of the $100SiO_2,20R_2O,x$PbO series have a higher density than the glasses of the $100SiO_2,40R_2O,x$PbO for corresponding values of x when the lead oxide content is greater than 10 molecules. Thus, above 10 molecules of lead oxide, the addition of alkali causes the density to fall. The broken line on Fig. 2 shows this, this line being curve I from Fig. 1.

Table II shows the density of alkali–lead oxide–silica glasses when comparison is made on the percentage basis. The compositions of the glasses will be found in Table I, the melt number, set, and section letter being given to facilitate cross-reference.

FIG. 2.



The following points are obvious from a study of this table:

(1) In every case investigated (SiO_2 between 30 and 70 per cent., PbO between 5 and 50 per cent., and alkali between 10 and 25 per cent.), the substitution of potash for soda per cent. for per cent. results in a decrease in density.

(2) The last column in Table II gives the fall in density in going from a soda glass to its corresponding potash glass. Where the lead oxide percentage becomes greater and the silica percentage less, it

will be noted that the fall in density due to the substitution of potash for soda becomes greater. On the other hand, if the silica remains constant, the fall in density due to substitution becomes less as the lead oxide increases and the alkali content decreases.

TABLE II.

Set.	Section.	Melt No.	Density	Difference between Na_2O and K_2O.
I.	*a*	186*A*	2·531	0·060
($SiO_2=70\%$)		187*A*	2·471	
	b	186*B*	2·610	
		188*B*	2·570	0·064
		187*B*	2·546	
	c	186*C*	2·701	0·057
		187*C*	2·644	
II.	*b*	186*E*	2·742	
($SiO_2=65\%$)		188*E*	2·714	0·063
		187*E*	2·679	
	c	186*F*	2·836	0·062
		187*F*	2·774	
III.	*a*	186*H*	2·783	0·071
($SiO_2=60\%$)		187*H*	2·712	
	b	186*J*	2·887	
		188*J*	2·845	0·068
		187*J*	2·819	
	c	186*K*	2·981	0·064
		187*K*	2·917	
	d	186*L*	3·075	0·064
		187*L*	3·010	
IV.	*b*	186*M*	3·172	
($SiO_2=50\%$)		188*M*	3·123	0·080
		187*M*	3·092	
	c	186*N*	3·268	0·079
		187*N*	3·189	
	d	186*P*	3·364	0·074
		187*P*	3·275	
V.	*b*	186*Q*	3·458	
($SiO_2=40\%$)		188*Q*	3·427	0·088
		187*Q*	3·370	
	c	186*R*	3·561	0·077
		187*R*	3·484	
	d	186*S*	3·665	0·073
		187*S*	3·592	
VI.	*b*	186*T*	3·742	
($SiO_2=30\%$)		188*T*	3·692	0·100
		187*T*	3·642	

(3) A comparison of the densities of the glasses containing respectively 70, 65, 60, 50, and 45 per cent. of silica shows that when Na_2O is substituted in a glass by PbO per cent. for per cent. there is a rise in density. This rise in density per 1 per cent. of PbO substituted has a mean value (1 per cent. of PbO $-$ 1 per cent. of Na_2O) of 0·020. The mean value for the corresponding K_2O glasses, namely, (1 per cent. of PbO $-$ 1 per cent. of K_2O), is 0·020. It follows that the addition of 1 per cent. of PbO to this type of glass

has the same effect upon density whether the glass contains Na_2O or K_2O, provided that the SiO_2 remains constant.

(4) When the densities of the glasses containing 15, 20, 30, 40, and 50 per cent. of lead oxide are compared, a mean rise in density of 0·0089 for (1 per cent. of $Na_2O - 1$ per cent. of SiO_2) is obtained. The corresponding rise for (1 per cent. of $K_2O - 1$ per cent. of SiO_2) is 0·0074. Therefore, when SiO_2 is substituted in a glass of this type by alkali per cent. for per cent. there is a rise in density. This rise is greater where the silica is substituted by Na_2O than when it is replaced by K_2O.

(5) Comparing the glasses containing 25, 20, 15, and 10 per cent. of sodium oxide, it will be seen that there is a mean rise in density for (1 per cent. of $PbO - 1$ per cent. of SiO_2) of 0·0284. The corresponding rise for the potash glasses (1 per cent. of $PbO - 1$ per cent. of SiO_2) is 0·0276. Thus when SiO_2 is substituted in a glass of this type by PbO per cent. for per cent. there is a rise in density, and this rise is the same (=0·028), whether the glass contains soda or potash.

FIG. 3.

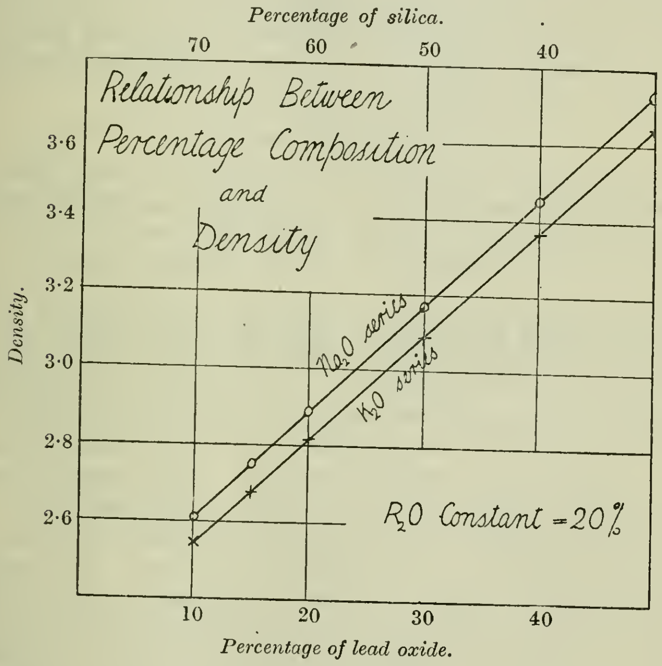


Fig. 3 shows the densities of the glasses *B*, *E*, *J*, *M*, *Q*, *T* in the two series 186 and 187. It illustrates very well the facts that (i) the density of a soda glass is higher than its corresponding potash glass, (ii) density increases as the PbO percentage increases, (iii) rate of increase of density in this series is constant, that is, density is additive in character when considered from the point of view of percentage increase by weight of lead oxide.

(6) From the results in the three preceding paragraphs it follows that:

1 per cent. of PbO $- \frac{1}{2}$ per cent. of $Na_2O - \frac{1}{2}$ per cent. of $SiO_2 =$ 0·0242.

1 per cent. of PbO $- \frac{1}{2}$ per cent. of $K_2O - \frac{1}{2}$ per cent. of $SiO_2 =$ 0·0238.

Thus if the percentage of PbO in a glass of the type under investigation is increased, and the difference spread equally over the silica and alkali, then the effect upon density of adding PbO is the same whether the glass contains Na_2O or K_2O, and is 0·024 per 1 per cent. addition of PbO.

2. *Refractive Index.*

The data which make possible a comparison of the effects on refractive index and dispersion of replacing, molecularly, sodium oxide by potassium oxide have already been given (this vol., pp. 302, 313, 323), and from them the following conclusions may be drawn:

(1) In all the above glasses which can be represented by the general molecular formula $100SiO_2,yR_2O,xPbO$, where y lies between 20 and 40 molecules and x between 5 and 40 molecules, increasing the lead oxide content increases both the refractive index for the D-line and the total dispersion. The rate of increase falls off as the molecular lead oxide content rises. This statement is probably true for all values of x and y capable of yielding glasses.

(2) In these glasses it will be noted that the lead oxide content plays the greatest part in determining both the η_D value and the total dispersion. Thus in any glass of the above general formula, whether R_2O denotes Na_2O, K_2O, or Na_2O,K_2O, the refractive index for the D-line and the total dispersions are very near one another. An examination of the tables shows that the maximum difference due to the substitution of soda wholly or in part by potash in the glasses investigated is only 0·004 in the refractive index of the D-line, and 0·0006 in the total dispersion. The glasses containing potash have a somewhat higher η_D value and total dispersion value than the corresponding soda glasses, whilst the mixed alkaline oxide glasses are intermediate.

(3) Comparing the series $100SiO_2,40R_2O,xPbO$ and

$$100SiO_2,20R_2O,xPbO,$$

it will be seen that when x is greater than 20 molecules the glass containing the less R_2O has the greater η_D value. Thus the addition of alkali, either soda or potash, to a lead glass of this type containing 20 molecules or upwards of lead oxide causes a drop in refractive index of the D-line.

(4) A comparison of the two series shows that the glasses containing $40R_2O$ have a higher $\eta_F - \eta_C$ value than the corresponding glasses of the $20R_2O$ series.

(5) In all the glasses of the $100SiO_2,yR_2O,xPbO$ type the ν value continually falls as the η_D value rises in a series (see Part VI, p 302, Part VII, p. 313, and Part VIII, p. 323). It is possible, however, by altering the alkali in a glass to *increase* the ν value when the η_D value increases. Thus the glass

$$100SiO_2,40Na_2O,20PbO$$

has $\eta_D = 1{\cdot}5927$ and ν value 38·9, whilst glass

$$100SiO_2,20Na_2O,20PbO$$

has $\eta_D = 1{\cdot}5930$ and ν value 39·6, and, further, glass

$$100SiO_2,20K_2O,20PbO$$

has $\eta_D = 1{\cdot}5940$ and ν value $= 39{\cdot}2$.

Percentage Composition and Refractive Index.

The refractive indices for the C, D, and F lines of the spectrum were obtained for the glasses melted according to the scheme outlined on p. 331, the basis for comparison being the percentage composition by weight.

No tests could be made with 186 *D*, 187 *D*, and 186 *G* owing to devitrification.

The results shown in Table III (p. 338) were obtained.

(1) In every case the refractive index for the D-line and the total dispersion are greater in the soda glass than in the corresponding potash glass. Thus, the addition of soda by weight to a glass of the type under discussion has a greater effect upon the refractive index than the addition of the same amount of potash by weight, provided that the remaining constituents of the glass are altered in the same way by the addition.

(2) From the first "difference" column in Table III it will be seen that in a series of glasses where the silica remains a constant percentage, the difference in η_D between the soda glass and its corresponding potash glass becomes less as the lead oxide content becomes greater. Similarly, it will be noted that where the lead oxide percentage is constant, the difference in the soda and potash glasses becomes less as the silica becomes greater (compare glasses *C*, *E*, *H*). Thus, in a series of glasses of the type $aSiO_2,bPbO,cR_2O$,

TABLE III.

Melt No.	η_D.	$(\eta_F-\eta_C)$ $\times 10^5$.	ν.	$(\eta_D-\eta_C)$ $\times 10^5$.	$(\eta_F-\eta_D)$ $\times 10^5$.	β.	Difference between Na_2O and K_2O glasses for η_D.	for $\eta_F-\eta_C$.
186*A*	1·5092	898	56·70	266	632	0·704		
187*A*	1·5023	818	61·40	243	575	0·703	0·0069	0·00080
186*B*	1·5154	950	54·25	280	670	0·705		
188*B*	1·5110	901	56·71	266	635	0·705	0·0067	0·00072
187*B*	1·5087	878	57·93	258	620	0·705		
186*C*	1·5197	1005	51·72	294	711	0·707		
187*C*	1·5151	940	54·80	276	664	0·706	0·0046	0·00065
186*E*	1·5298	1072	49·43	313	759	0·708		
188*E*	1·5265	1022	51·52	300	722	0·707		
187*E*	1·5248	998	52·59	292	706	0·707	0·0050	0·00074
186*F*	1·5349	1126	47·50	328	798	0·709		
187*F*	1·5319	1063	50·03	310	753	0·708	0·0030	0·00063
186*H*	1·5419	1140	47·53	332	808	0·709		
187*H*	1·5350	1071	49·96	312	759	0·709	0·0069	0·00069
186*J*	1·5475	1195	45·82	347	848	0·710		
188*J*	1·5434	1151	47·21	334	817	0·710		
187*J*	1·5415	1128	48·01	328	800	0·709	0·0060	0·00067
186*K*	1·5517	1253	44·03	362	891	0·711		
187*K*	1·5487	1203	45·62	349	854	0·710	0·0030	0·00050
186*L*	1·5568	1319	42·22	380	939	0·712		
187*L*	1·5558	1263	44·00	364	899	0·712	0·0010	0·00056
186*M*	1·5822	1451	40·01	416	1035	0·713		
188*M*	1·5778	1401	41·25	403	998	0·713		
187*M*	1·5754	1378	41·76	397	981	0·712	0·0068	0·00073
186*N*	1·5869	1511	38·67	434	1077	0·713		
187*N*	1·5824	1442	40·38	415	1027	0·713	0·0045	0·00069
186*P*	1·5915	1570	37·68	451	1119	0·713		
187*P*	1·5903	1510	39·09	434	1076	0·713	0·0012	0·00060
186*Q*	1·6165	1700	36·27	488	1212	0·713		
188*Q*	1·6114	1651	37·02	474	1177	0·713		
187*Q*	1·6088	1625	37·47	466	1159	0·713	0·0077	0·00075
186*R*	1·6219	1764	35·26	501	1263	0·716		
187*R*	1·6176	1694	36·45	483	1211	0·715	0·0043	0·00070
186*S*	1·6262	1828	34·26	519	1309	0·716		
187*S*	1·6248	1760	35·50	500	1260	0·716	0·0014	0·00068
186*T*	1·6509	1955	33·30	553	1402	0·717		
188*T*	1·6465	1904	33·94	541	1363	0·716		
187*T*	1·6442	1882	34·22	535	1347	0·716	0·0067	0·00073

where $(a+b+c)=100$ per cent., the greater the value of c the greater will be the difference in refractive index between the soda and potash glasses when either a or b is constant in the series.

(3) It will be observed from the above that the difference between the refractive index for the *D*-line for a soda glass and its corresponding potash glass is not a constant, but varies according to the amount of silica or lead oxide in the glass. Thus, the glass $70SiO_2,15PbO,15Na_2O$ has η_D 0·0046 higher than that of $70SiO_2,15PbO,15K_2O$, whilst the glass $60SiO_2,15PbO,25Na_2O$ has η_D 0·0069 higher than that of $60SiO_2,15PbO,25K_2O$.

(4) The second "difference" column in Table III shows that, as in the case of refractive index, the difference in total dispersion between soda and potash glasses becomes less when either the lead oxide percentage or the silica percentage increases.

(5) Fig. 4 shows diagrammatically the rise in refractive index as the percentage of lead oxide increases and the percentage of alkali decreases, the silica remaining constant.

(6) It will be seen that the rate of increase for (+1 per cent. of PbO − 1 per cent. of K_2O) is greater than for (+1 per cent. of PbO − 1 per cent. of Na_2O).

Fig. 5 shows the increase in total dispersion for the same glasses.

(7) A study of the optical constants of the glasses 186 *A*, *B*, *C*, 186 *E*, *F*, 186 *H*, *J*, *K*, *L*, and 186 *Q*, *R*, *S* shows that the mean rise in refractive index of the *D*-line for (1 per cent. of PbO − 1 per cent. of Na_2O) is 0·0010.

FIG. 4

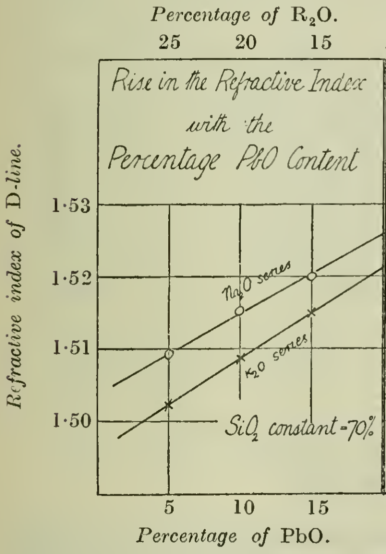
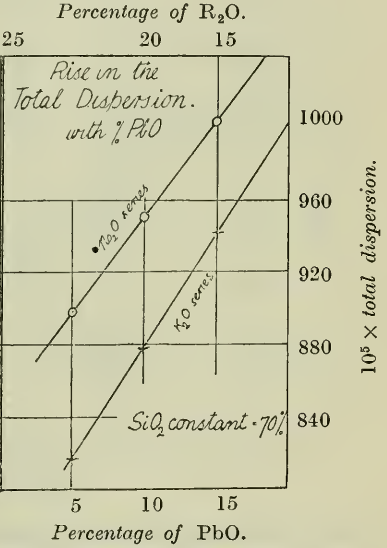


FIG. 5.



The increase in total dispersion for (1 per cent. of PbO − 1 per cent. of Na_2O) is 0·00012.

From the corresponding potash glasses in the 187 series the values are as under:

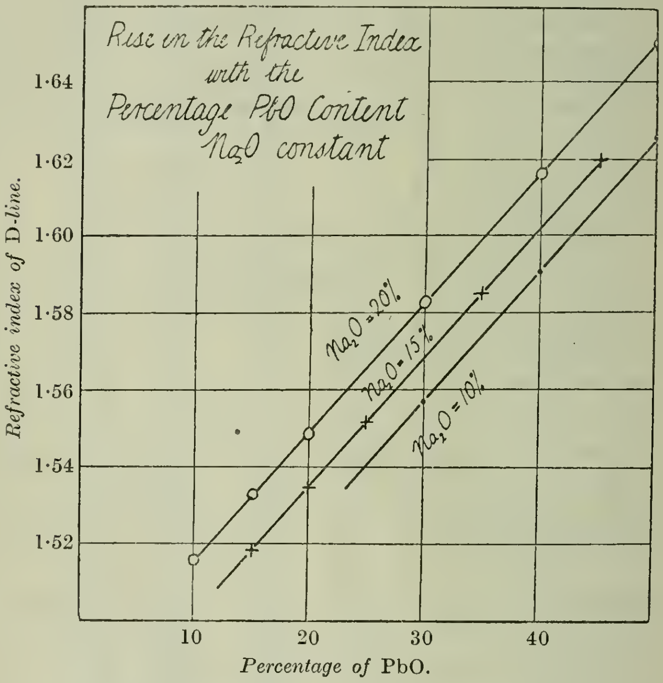
Rise in η_D for (1 per cent. of PbO − 1 per cent. of K_2O) is 0·0014.

Rise in total dispersion for (1 per cent. of PbO − 1 per cent. of K_2O) is 0·00012.

Thus, substitution of lead oxide for potash weight for weight has a somewhat greater effect upon η_D than the substitution for soda, whilst the total dispersion is affected by the same amount, whether soda or potash is replaced by lead oxide.

(8) The rise in refractive index of the *D*-line, due to increasing the percentage of lead oxide and diminishing the percentage of silica, the soda being kept constant, is shown in Fig. 6. The curves for the corresponding potash glasses are not shown on the diagram. They are parallel to those for the soda glasses, and slightly lower in each case, being nearer the smaller the amount of alkali in the glass. Fig. 7 shows the rise in total dispersion for the same glasses.

FIG. 6.



(9) The rate of increase per (1 per cent. of PbO − 1 per cent. of SiO_2) for both η_D and total dispersion is approximately the same for both the soda and potash glasses, as well as for the glasses containing equal percentages of both alkaline oxides. This rate of increase is constant, showing that refractive index is additive in character when viewed from the point of view of percentage composition by weight of the glass.

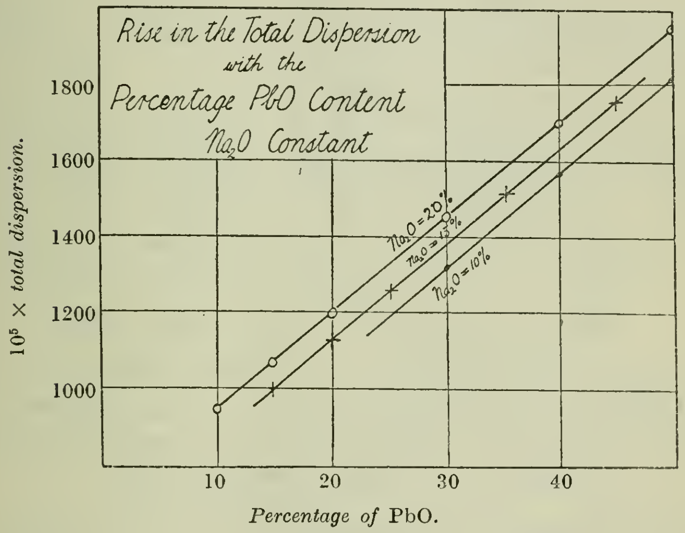
(10) Examination of the refractive indices of the glasses 186 and 187 *A*, *H*, 186, 187, and 188 *B*, *E*, *J*, *M*, *Q*, *T*, 186 and 187 *C*, *F*,

K, *N*, *R*, and 186 and 187 *L*, *P*, *S*, yields information which may be most briefly summarised in the following statement:

Na_2O series (+1% PbO − 1% SiO_2) = +0·0034 = rise in η_D
= +0·00026 = rise in total dispersion
K_2O series (+1% PbO − 1% SiO_2) = +0·0034 = rise in η_D
= +0·0026 = rise in total dispersion
Na_2O,K_2O series (+1% PbO − 1% SiO_2) = +0·0034 = rise in η_D
= +0·00025 = rise in total dispersion.

(11) A comparison of the numbers obtained in (6) and (7) with those in (10) proves that if 1 per cent. of lead oxide be introduced into a glass of this type and 1 per cent. of silica subtracted to compensate, the alkali being kept constant, the rise in the refractive index of the *D*-line and in the total dispersion is greater than if 1 per cent. of alkali were subtracted to compensate, the silica being kept constant.

FIG. 7.



This once more emphasises the point that it is impossible to say what will be the effect of the addition of 1 per cent. of any substance to a glass unless it is specified how the remaining oxides in the glass are altered.

(12) The increase in η_D due to increasing the alkali oxide, the percentage of lead oxide remaining constant, is shown diagrammatically in Fig. 8. Two sets of glasses are shown. In the first set (186 *C*, *E*, *H* and 187 *C*, *E*, *H*) the percentage of lead oxide is 15 and in the second set (186 *D*, *F*, *J* and 187 *D*, *F*, *J*) it is 20 per

cent. The values of the two glasses 186 *D* and 187 *D* are extrapolated.

It will be noted that the increase for (+1 per cent. of Na_2O – 1 per cent. of SiO_2) is greater than for (+1 per cent. of K_2O – 1 per cent. of SiO_2).

(13) Fig. 9 shows the total dispersions of the above two sets of glasses.

FIG. 8.

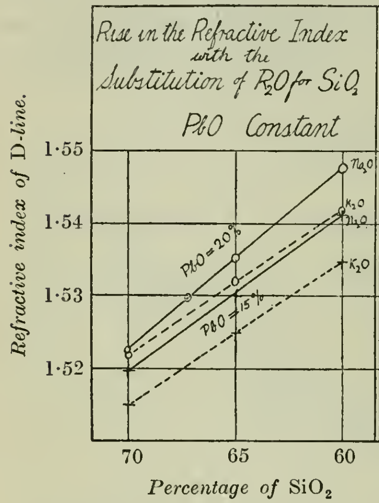
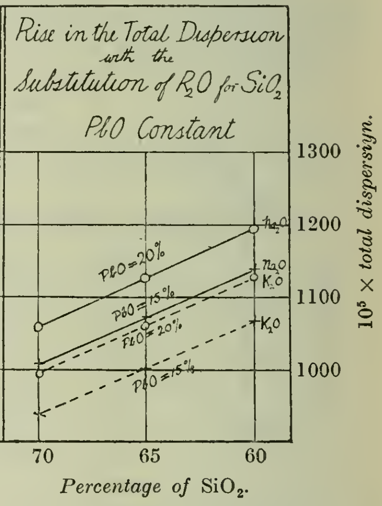


FIG. 9.



(14) The results for the glasses 186 *C*, *E*, *H*, 186 *F*, *J*, 186 *L*, *M*, 186 *P*, *Q*, and 186 *S*, *T* yield the following mean values:

$$(+1\%\ Na_2O - 1\%\ SiO_2) = +0{\cdot}0024 = \text{rise in } \eta_D$$
$$= +0{\cdot}00013 = \text{rise in } \eta_F - \eta_C$$

The corresponding values for the potash glasses of 187 series are:

$$(+1\%\ K_2O - 1\%\ SiO_2) = +0{\cdot}0019 = \text{rise in } \eta_D$$
$$= +0{\cdot}00012 = \text{rise in } \eta_F - \eta_C$$

(15) From the numbers previously obtained in paragraphs (6), (7), and (10) it follows that:

$$(+1\%\ PbO - \tfrac{1}{2}\%Na_2O - \tfrac{1}{2}\%SiO_2) = +0{\cdot}0022\ (\eta_D) \text{ and } +0{\cdot}00019\ (\eta_F - \eta_C)$$
$$(+1\%\ PbO - \tfrac{1}{2}\%K_2O - \tfrac{1}{2}\%SiO_2) = +0{\cdot}0024\ (\eta_D) \text{ and } +0{\cdot}00019\ (\eta_F - \eta_C)$$

Thus in glasses of the $a SiO_2, b PbO, c R_2O$ type, where $(a + b + c) =$ 100 per cent., when b is increased to $(b + 1)$ per cent. the rise in total dispersion is the same, whether R_2O is represented by soda or by potash, granted that the percentage difference is spread equally over the other two constituents. This rise in $\eta_F - \eta_C = 0{\cdot}00019$. The rise in η_D is 0·0022 when the glass contains soda and 0·0024 when potash is the alkali oxide.

(16) From paragraphs (6), (7), and (14) the following values are noteworthy:

$$(+1\%\ Na_2O - \tfrac{1}{2}\%\ PbO - \tfrac{1}{2}\%\ SiO_2) = +0{\cdot}0007\ \eta_D \text{ and } 0{\cdot}0\ (\eta_F - \eta_C)$$
$$(+1\%\ K_2O - \tfrac{1}{2}\%\ PbO - \tfrac{1}{2}\%\ SiO_2) = +0{\cdot}0003\ \eta_D \text{ and } 0{\cdot}0\ (\eta_F - \eta_C)$$

and from them the rather remarkable and useful fact comes to light that in a glass of the type $a SiO_2, b PbO, c R_2O$, where $(a+b+c)=100$ per cent., if c is increased to $(c+1)$ per cent. and the 1 per cent. difference spread equally over the other two oxides, then there is no alteration* in the total dispersion, whether R_2O is represented by soda or by potash.

When R_2O denotes soda, then there is a rise of 0·0007 in η_D; if R_2O denotes potash, then η_D rises 0·0003.

The above facts are useful where it is necessary to make a small alteration to a batch for this type of glass, in order to raise the η_D value slightly without altering the total dispersion. It will be seen that more than twice the rise is obtained in the η_D value by using soda than by using the same amount of potash. The drawback to using the method to obtain larger rises in η_D without altering the total dispersion is the fact that the glass becomes increasingly less durable with a rise in alkali content.

(17) Examination of the numbers in paragraphs (10) and (14) leads to the following constants:

$$(+1\%\ SiO_2 - \tfrac{1}{2}\%\ PbO - \tfrac{1}{2}\%\ Na_2O) = -0{\cdot}0029\ (\eta_D) \text{ and } -0{\cdot}00019\ (\eta_F - \eta_C)$$
$$(+1\%\ SiO_2 - \tfrac{1}{2}\%\ PbO - \tfrac{1}{2}\%\ K_2O) = -0{\cdot}0027\ (\eta_D) \text{ and } -0{\cdot}00019\ (\eta_F - \eta_C)$$

Thus the refractive index for the *D*-line and the total dispersion of a lead glass of the types under discussion can be reduced by adding silica.

(18) The following general statement is deduced from the last three paragraphs. In glasses of the type $a SiO_2, b PbO, c R_2O$, where $(a+b+c)=100$ per cent., if the lead oxide is increased 1 per cent. and the difference is spread equally over the soda and silica, both the refractive index of the *D*-line and the total dispersion are increased. If the R_2O is increased 1 per cent. and the difference spread equally, the refractive index increases, but the total dispersion remains unaltered.* Where the silica is increased 1 per cent. and the difference is spread equally, both η_D and $(\eta_F - \eta_C)$ decrease.

3. *Devitrification.*

The results of the devitrification tests † for the molecular series $100SiO_2, 40R_2O, x PbO$ and the series $100SiO_2, 20R_2O, x PbO$ have been given previously.

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* No alteration in $(\eta_F - \eta_C)$ to the fifth place of decimals.

† This vol., TRANS., pp. 306, 317, 326.

The following conclusions are to be drawn:

(1) None of the potash glasses of the two molecular series $100SiO_2,40K_2O,x PbO$ and $100SiO_2,20K_2O,x PbO$ showed any tendency to devitrification in the body of the glass. It should be observed, however, that all these glasses were covered with a semi-opaque crinkled skin. This skin is very pronounced in the glasses containing a high potash content, and improves as the potash content decreases. The skin appears to be purely a surface phenomenon, and cannot be regarded as devitrification of that type which is likely to occur in the whole mass of glass. In all probability the surface layers of the glass lose a high proportion of their potash by volatilisation, with the result that the surface layer is no longer vitreous. The appearance is very like that obtained when glass tubing containing a large proportion of alkali is worked for a considerable time in a blowpipe flame.

(2) Of the soda glasses in the molecular series

$$100SiO_2,40Na_2O,x PbO,$$

none showed any signs of devitrification. The first two glasses of the series, containing 5 molecules and 10 molecules of lead oxide respectively, had upon their surface patches of a film which was distinctly crystalline in appearance. This film appears to be purely a surface phenomenon, and perhaps is due to what may be termed "surface devitrification." Photomicrograph (1) (facing p. 346) shows the appearance of the film, the magnification being 17½ diameters; photomicrograph (2) (facing p. 346), magnification 4½ diameters, shows a similar film formed on a large melt under more perfect conditions. It will be seen that the markings, although similar in their general configuration, are more perfect and decisive in the second photograph. The crystals formed seem to be silica, and a comparison with later photomicrographs (Nos. 6 to 12) of silica crystals from a melt is of interest. In all probability the top layer of the glass loses soda by volatilisation and becomes rich in silica, which separates out. The later glasses of the series have a clear bright surface which shows no signs of a crystalline film.

In the early days of optical glass manufacture in the Derby works, when these crystalline surface deposits sometimes appeared on the surface of glass after cooling, the author considered the possibility of a deposition of a crystalline substance or substances from the atmosphere above the surface of the glass in a closed pot. During a melting the atmosphere above the molten glass may contain alkali, carbon dioxide, boric oxide (if borax is used in the batch), silica (this is probably volatile), and other compounds. On cooling, it was thought that some of these substances might unite, giving, say, carbonates, borates, or silicates, and, being deposited on the soft glass surface, might embed themselves in it as crystals. Microscopical examination showed the crystals to be solely silica, and the view that silica alone might be deposited was next entertained. If this view were a true one, then the fact that silica was volatile during glass melting would be established. Further investigation proved the view to be untenable. Thus the crystals were only found on the surface of certain types of glass, and these not necessarily rich in silica. Again, if several glasses were heated in separate containers in the same closed muffle, some had upon their surface the crystalline film and others had not. If the silica were deposited from the atmosphere above the molten glasses it should be deposited on all. Bearing these facts in mind, it seems established that this crystalline film is due to surface devitrification, silica separating out. On occasion, this surface devitrification may extend to layers beneath. An example of this was found in a fluor-crown melting, which gave a beautiful glass in bulk. The top of the melting was covered with a white, opaque sheath about 0·5 millimetre in thickness, and growing downwards into the melting to a depth of about 5 millimetres were innumerable white "hairs." Under the microscope these showed up as long, needle-like crystals apparently hexagonal in cross-section, and they may be a silicate or some other compound. Photomicrograph 3 (facing p. 346) shows the appearance of these crystals magnified 15 diameters.

In the series $100SiO_2,20Na_2O,xPbO$ the glass containing 5 molecules of lead oxide became a white, porcelain-like mass exhibiting total devitrification, due to a separation of silica. The glass containing 10 molecules of lead oxide was partly devitrified, but none of the other glasses of the series showed any signs of devitrification or filming.

(3) In the series $100SiO_2,20Na_2O,20K_2O,xPbO$ none of the glasses devitrified. All except the one containing 40 molecules of lead oxide (which had a bright surface) showed both the characteristic "crinkled" skin of the potash glasses and also the crystalline film of the soda glasses.

The first glass in the series $100SiO_2,10Na_2O,10K_2O,xPbO$, containing 5 molecules of lead oxide, became a white, porcelain-like mass showing total devitrification, and the glass containing 10 molecules of lead oxide partly devitrified. The remaining glasses of the series did not devitrify, but two of them containing 15 and 20 molecules of lead oxide respectively showed the characteristic skin of the potash glasses.

(4) All the glasses of the $100SiO_2,40R_2O,xPbO$ series melt down and completely fill the container at 900°. In the series

$$100SiO_2,20R_2O,xPbO$$

only those glasses containing 20 molecules or more of lead oxide melt down completely.

(5) Speaking generally, the soda glasses of the type under discussion show total devitrification when the silica content is 70 per cent. or more, and have a tendency to devitrify when it exceeds 60 per cent. On the other hand, the potash glasses show no tendency to devitrify under the same conditions. The glasses containing both soda and potash are like the soda glasses, tending to devitrify when the silica content exceeds 60 per cent. It will be seen, therefore, that in lead glasses where the silica content is more than 60 per cent. there is a tendency to devitrification with a separation of silica, when the whole or part of the alkaline oxide present is soda.

(6) Crystalline filming is only observed in those lead glasses containing some soda and only when the total alkali content is more than 15 per cent. The "crinkled" skin appearance is found only in glasses containing some potash. This crinkled skin shows well in photomicrograph 1.

Percentage Composition and Devitrification.

Table IV shows the devitrification results for the glasses the compositions of which are set out in Table I (p. 331) in percentage composition by weight.

From the results in this table a very comprehensive view of the relative effects of soda and potash upon devitrification of lead glasses, regarded from the point of view of equivalent percentage by weight, may be obtained.

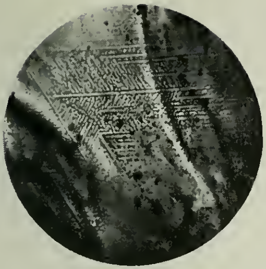
In the last column an attempt is made to show the order in which the glasses flowed down at 900°, an estimate being obtained from the appearance of the glasses after the devitrification test. The following points require notice where the melting points of these glasses are concerned:

(1) In every case, whatever the percentage of silica or lead oxide present, the soda glass is more easily melted than the potash glass, proving that, weight for weight, soda is a better flux than potash.

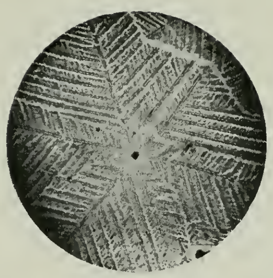
(2) Where the silica remains constant in a series of glasses, the substitution of lead oxide for alkali raises the melting point in a slight degree.

(3) The substitution of either lead oxide or alkali for silica lowers the melting point.

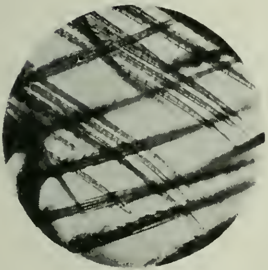
(4) Where the alkali content is in equal amounts by weight of soda and potash, the melting is intermediate between that of soda and potash glasses, tending to be nearer the soda glasses.



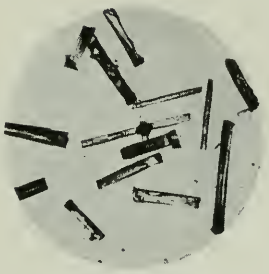
No. 1. × 17½ diameters.



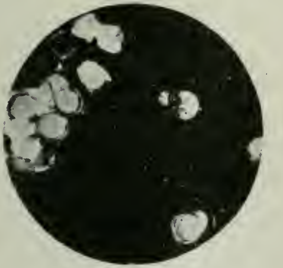
No. 2. × 4½ diameters.



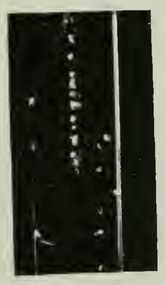
No. 3. × 15 diameters.



No. 4. × 3½ diameters.

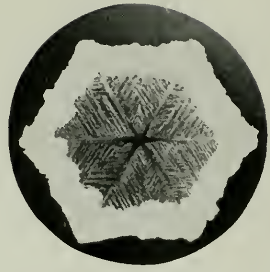


No. 5. × 4½ diameters.

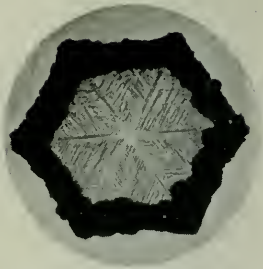


No. 6. Same size.

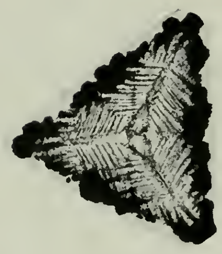
[*To face p.* 346 *Trans.*



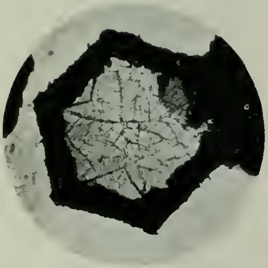
No. 7. × 35 diameters.



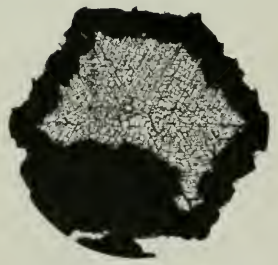
No. 8. × 35 diameters.



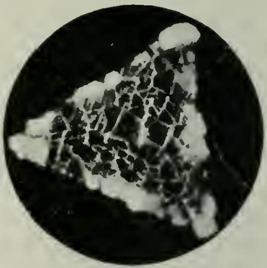
No. 9. × 35 diameters.



No. 10. × 35 diameters.



No. 11. × 35 diameters.



No. 12. × 35 diameters.

TABLE IV.

Set.	Section.	Melt No.	Devitrification.	Result.	Melting result.	Order of flowing down.
I. SiO_2= 70%	*a*	186*A*	No devitrification	Clear and bright	Melted	6
		187*A*	,,	Slight skin	,,	8
	b	186*B*	,,	Clear	,,	6
		188*B*	,,	,,	,,	6
		187*B*	,,	Slight skin	,,	9
	c	186*C*	Devitrified	—	Not melted	18
		187*C*	,,	—	,,	19
II. SiO_2= 65%	*b*	186*E*	No devitrification	Clear	Melted	5
		188*E*	,,	,,	,,	5
		187*E*	,,	Slight skin	,,	7
	c	186*F*	Partial devitrification		Partly melted	10
		187*F*	Incipient devitrification		Just melted	14
	d	186*G*	Total devitrification		Not melted	16
		187*G*	,,		,,	17
III. SiO_2= 60%	*a*	186*H*	No devitrification	Clear	Melted	4
		187*H*	,,	Very slight skin	,,	4
	b	186*J*	,,	Clear	,,	4
		188*J*	,,	,,	,,	4
		187*J*	,,	Very slight skin	,,	5
	c	186*K*	,,	Clear	,,	7
		187*K*	,,	Slight skin	,,	12
	d	186*L*	Devitrified		Not melted	15
		187*L*	Slight devitrification	Bad skin	Partly melted	13
IV. SiO_2= 50%	*b*	186*M*	No devitrification	Clear	Melted	3
		188*M*	,,	,,	,,	3
		187*M*	,,	,,	,,	3
	c	186*N*	,,	,,	,,	3
		187*N*	,,	Faint skin	,,	4
	d	186*P*	,,	Clear	,,	3
		187*P*	,,	Faint skin	,,	11
V. SiO_2= 40%	*b*	186*Q*	,,	Clear	,,	2
		188*Q*	,,	,,	,,	2
		187*Q*	,,	Faint skin	,,	2
	c	186*R*	,,	Clear	,,	2
		187*R*	,,	Faint skin	,,	3
	d	186*S*	,,	Clear	,,	2
		187*S*	,,	,,	,,	3
VI. SiO_2= 30%	*b*	186*T*	,,	,,	,,	1
		188*T*	,,	,,	,,	1
		187*T*	,,	Slight skin	,,	2

The following observations are of interest regarding the devitrification of lead glasses from the point of view of percentage composition by weight:

(1) In a series of glasses where the silica remains constant the tendency to devitrification is increased as the lead oxide increases and the alkali content falls.

(2) When devitrification takes place it is in the form of a separation of silica.

(3) The separation of silica is more marked in the soda–lead oxide glasses than those containing potash–lead oxide, and was a prolific cause of trouble in the manufacture of certain flint glasses during the war. Owing to the scarcity and dearness of potash salts, soda salts had to be used to provide the necessary alkaline flux. Even when the percentage amounts of silica and lead oxide in the glasses were kept the same (that is, potash was replaced weight for weight by soda), in certain circumstances glass full of white aggregations was obtained. This state of affairs was caused by silica separating out of the melt with greater ease in the presence of soda than it would do in the presence of potash. The remedy lay in decreasing the silica percentage and increasing this alkali or lead oxide, the latter for preference, in order to preserve the durability of the glass.

This separation of silica from soda–lead glasses with greater ease than from potash–lead glasses explains certain devitrification results reported by Le Chatelier.* Two varieties of flint glass were being melted side by side. The batch for the first glass contained approximately 55 per cent. of silica, 35 per cent. of lead oxide, and 10 per cent. of potash. The batch of the second glass contained $55SiO_2,35PbO,8Na_2O,2K_2O$ in approximate percentages. The first batch was used with cullet in the proportion of 1 part of batch to $2\frac{1}{2}$ parts of cullet. The second batch was used with cullet in the proportion of 1 part of batch to 4 parts of cullet. The use of cullet, from which some of the original alkali would have volatilised, would serve to raise the silica content in each glass, and more in the soda glass than in the potash one.

The furnace in which the glasses were being melted was partly shut down, owing to the shelling of the factory by the Germans, and was kept at a temperature of about 800° for some three weeks. It was then cooled down entirely, when it was discovered that the soda–lead–glass had devitrified, silica having separated out, whilst the potash glass was unaltered.

In view of what is said later in this paper on the separation of silica from lead glasses (p. 349), it is of interest to note that Le Chatelier reported the devitrification above to be in the form of very thin hexagonal plates or in bunches, like spherulites, distributed in the clear glass, the crystals being *tridymite*. It should be noted that the author's work was carried out and his conclusions drawn before he was aware of this report of Le Chatelier on the devitrification of flint glass.

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* *Compt. rend.*, 1916, 110. This JOURNAL, **1**, Abs. p. 28.

(5) No separation of a lead silicate could be induced, although some of the glasses melted contained as much as 50 per cent. of lead oxide. Thus in glasses of the $a\mathrm{SiO}_2,b\mathrm{R}_2\mathrm{O},c\mathrm{PbO}$ type, where $(a+b+c)=100$ per cent., it can be said from the results in Table IV that up to a lead content of 50 per cent. any devitrification will be due to a separation of silica.

The author has made lead glasses containing as much as 75 per cent. of lead oxide, the remainder being mostly silica. These glasses do not devitrify when melted under the conditions outlined in these papers, or under the devitrification tests described therein. They can be made to devitrify under certain known conditions and they deposit prismatic colourless crystals of lead monosilicate ($PbSiO_3$). Only under these particular conditions and only with these glasses of very high lead oxide content has lead silicate ever been isolated.

Photomicrograph 4 (facing p. 346) shows the appearance of these lead silicate crystals, a few of which were half an inch long and two millimetres thick, although the majority were only 2 to 5 millimetres in length. The magnification of the photograph is $3\frac{1}{2}$ diameters. It will be noted that the crystal shape is very well defined, a perfect crystal being a rectangular prism with a square cross section. When viewed by polarised light the crystals exhibit beautiful colour effects. Several of the crystals appeared to have in them bubbles of gas. The middle crystal on the photomicrograph shows such a bubble very plainly. In places in the glass spheroids were formed composed of masses of hair-like crystals. The bulk of the glass was made up of minute crystals, the larger crystals as shown in the photomicrograph being only found in fissures in the crystallised mass.

(6) When silica separates out from a small melting, in cooling down in the furnace it may cause the whole melt to appear as a white, opaque mass. On the other hand, where devitrification is not so pronounced, it separates in the form of small, white, opaque "blobs" varying in size up to a millimetre in diameter. To the naked eye some of these may be spherical in appearance, others more or less irregular in outline. Under the microscope, they appear to be made up of clusters of "blobs." Often each "blob" is accompanied by what appears to be a bubble, and this "bubble" appearance is characteristic of silica separations of this kind. Viewed under the microscope, this "bubble" appearance resolves into fractures of the glass, and it would appear that the silica in separating causes the glass round about it to fracture, the lines of fracture following the shape of the silica "blob." Occasionally, the glass near the silica can be seen to be non-homogeneous,

having patches in it which transmit light differently from the body of the glass. Photomicrograph 5 shows the appearance of these silica "blobs" in a small melt (181*A*), a thin horizontal section of the melt being used. The "blobs" are magnified $4\frac{1}{2}$ diameters. Around several of the "blobs" will be seen the characteristic fracture, which often makes them appear to the naked eye as if accompanied by a bubble in the glass. The black portion of the photograph represents the glass from which the "blobs" have separated out, and the very small white spheres are air bubbles.

(7) Where the cooling of a melt of the $a\mathrm{SiO}_2,b\mathrm{R}_2{}'\mathrm{O},c\mathrm{RO}$ type containing 60 to 70 per cent. of silica is very slow, say more than one hundred hours instead of twelve hours, some of the silica may separate out in the form of white, opaque "blobs," but occasionally beautiful crystalline forms are obtained. Some of these appear hexagonal and others triangular, and are probably silica in the form of tridymite. They vary in size and some are about a millimetre across. Often the separation will take place along striæ, and there appears in the glass a veritable "necklace" of alternating hexagonal, triangular, and opaque silica formations. One beautiful example shows the separation in striæ coloured green by an iron compound. Photomicrograph 6 shows a "string" of crystals in glass, same size. It will be seen that the definition of the crystals varies owing to their being at different depths beneath the glass surface. The glass from which these crystals separated only contained 62 per cent. of silica, its lead oxide content being 25 per cent.

Almost without exception the hexagonal and triangular crystals are edged with opaque, white silica. This under a high magnification appears to be composed of innumerable crystals. Photomicrograph 7 shows one of the hexagonal crystals seen by reflected light when the white, opaque edge shows up well. The same crystal photographed by transmitted light is shown in photomicrograph 8. Here the opaque edge shows up black, but the beautiful internal structure is at once apparent. Unfortunately, it was not possible to get the whole of the crystal in focus at once, as it did not lie horizontally in the micro-slide.

It may be of interest here to refer to a crystal formation in a piece of optical glass reported by J. W. French.* The report is accompanied by a photomicrograph which is reproduced in the *Optician*, 1920, **59**, No. 1535, 356. The optical glass in which the crystal was observed is stated to be a flint, but no attempt is made to identify the crystal. The crystal was observed in a moulded slab, and it is suggested that in the original glass a small particle rich in some particular constituent was flattened on moulding into a thin layer parallel to the surface of the slab, and this layer subsequently crystallised. From the appearance of the crystal and from the notes accompanying it as to its behaviour under the microscope, it is identical in composition with the crystal shown in photomicrographs 7 and 8 and is therefore silica. It should be remarked that the crystal shows none of the opaque edge silica shown in photomicrograph 7. Examination of photomicrograph 8 shows that there is a small central portion of this crystal, a six-pointed star in shape, which shows no markings. In the crystal described by French this central portion showing no crystallisation is very large, occupying more than half the width of the crystal. From the evidence of the crystals described in this paper and from French's crystal it would appear that the opaque edge formation is of later growth than that of the crystal itself.

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* *Trans. Optical Soc.*, 1916, **6**, 224; this JOURNAL, 1, Abs. 59.

Photomicrograph 9 shows a triangular crystal taken by transmitted light, the edge appearing black. It will be seen that the angle between the principal lines of demarcation of the triangular crystal is 120°, whilst in the hexagonal crystals the angle between these lines is 60°. Another difference to be found in the two formations is the appearance of the central portion. In the hexagonal crystal this is without crystal markings, but in the triangular crystal it is full of characteristic markings. It will be noted, too, that in the hexagonal crystal the "branchings" from the main demarcation lines converge towards the centre of the crystal, whilst in the triangular crystals these "branchings" diverge from the centre.

Some of the crystals appear fractured. Photomicrograph 10 shows a hexagonal crystal, which has irregular fracture marks superimposed on the markings of the crystal. These fractures are probably in the thin layer of glass immediately above the crystal.

Photomicrograph 11 is a beautiful example of fracture, the fractures here appearing to be in the crystal itself. It will be seen that the original lines of demarcation of the crystal are very obvious and the fractures are mostly at right angles or parallel to these lines. Photomicrograph 12 shows fracture with a triangular crystal taken by reflected light.

The photomicrographs 7—12 (facing p. 347) show the crystals magnified 35 diameters.

4. *Solubility.*

Making use of the solubility data previously recorded on pp. 307, 317, 327, it is possible to draw definite inferences on the effect of replacing soda step by step by potash in lead glasses.

These inferences are:—

(1) the solubilities of glasses containing potash are much greater than the solubilities of the corresponding soda glasses containing the same molecular proportions.

(2) The solubilities of glasses containing equimolecular proportions of both soda and potash are intermediate between those of the corresponding soda and potash glasses, being nearer those of the soda glasses.

(3) The solubility of a glass depends largely on the amount of alkali it contains, and as the alkali decreases the solubility decreases.

(4) The addition of either silica or lead oxide causes the solubility to decrease, but the power of these to lower solubility falls away as the alkali content becomes greater. Thus more than 30 per cent. of the glass $100SiO_2,20Na_2O,20K_2O,10PbO$ dissolves in water under the conditions of the solubility test, although the lead oxide content is nearly 20 per cent., the alkali being 27 per cent. On the other hand, the glass $100SiO_2,10Na_2O,10K_2O,5PbO$, although it only contains about 13 per cent. lead oxide, has a solubility less than 3 per cent. because the alkali content has fallen to 18 per cent.

(5) During the treatment of these glasses in powdered form with water at 80°, it was noted that in every case where the alkali content was greater than 20 per cent. a gelatinous material was formed. This material was the more pronounced as the alkali content became larger. It furnishes evidence of reaction between the water and the glass, with the formation of new substances, probably hydrated silicates.

Solubility from the Point of View of Percentage Composition by Weight.

Table V states the solubility of the glasses of the type $a\mathrm{SiO_2},b\mathrm{R_2O},c\mathrm{PbO}$, where $(a+b+c)=100$ per cent.

The solubilities of the glasses are given under the three heads (1) "weight dissolved," (2) "milligrams of H_2SO_4," (3) "milligrams of alkali." No great stress can be laid upon the values under "weight dissolved," as in some of the glasses (186 *A*, *B*, in the soda series and 187 *A*, *B*, *E*, *H*, in the potash series) a gelatinous material was formed during the test. All the glasses which gave this gelatinous material contained upwards of 20 per cent. of alkali (cp. p. 307). Sometimes the "jelly" is flocculent and occasionally "set" and difficult to remove.

The numbers under "milligrams of H_2SO_4"* serve as the best

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* This vol., TRANS., p. 94.

TABLE V.

Set.	Section.	Melt No.	Weight dissolved per 100 gm. of glass. gms.	Milligrams of H_2SO_4.	Milligrams of alkali.
I. $SiO_2=70\%$	*a*	186*A*	82·45	34200	21670
		187*A*	47·44	17460	16790
	b	186*B*	10·91	9232	5801
		188*B*	21·51	11510	9177
		187*B*	19·91	11390	10950
	c	186*C*	2·81	2906	1839
		187*C*	1·92	1696	1670
II. $SiO_2=65\%$	*b*	186*E*	10·92	9809	6205
		188*E*	3·93	3922	3128
		187*E*	9·00	6645	6395
	c	186*F*	2·98	2544	1610
		187*F*	1·84	1214	1169
III. $SiO_2=60\%$	*a*	186*H*	37·70	23110	14620
		187*H*	42·61	17650	16980
	b	186*J*	7·12	7891	4992
		188*J*	2·29	3523	2809
		187*J*	10·95	7775	7482
	c	186*K*	1·76	2122	1343
		187*K*	1·80	848	816
	d	186*L*	1·14	447	283
		187*L*	1·08	208	204
IV. $SiO_2=50\%$	*b*	186*M*	2·57	4884	3090
		188*M*	1·48	3169	2527
		187*M*	3·40	4614	4440
	c	186*N*	1·41	1395	883
		187*N*	0·82	798	768
	d	186*P*	0·53	300	190
		187*P*	0·42	163	157
V. $SiO_2=40\%$	*b*	186*Q*	1·14	4052	2564
		188*Q*	1·11	2794	2228
		187*Q*	4·47	6645	6395
	c	186*R*	1·11	1398	885
		187*R*	1·09	845	813
	d	186*S*	0·52	242	153
		187*S*	0·50	157	151
VI. $SiO_2=30\%$	*b*	186*T*	1·98	4607	2915
		188*T*	0·93	3920	3127
		187*T*	1·43	9164	8818

indication of the relative solubilities of the glasses, and are used in drawing the following conclusions:—

(1) Comparing the relative effect of soda and potash from the point of view of percentage substitution by weight, where the alkali content is greater than 20 per cent. the potash glass has a higher solubility than the corresponding soda glass (compare glasses *B*, *E*, *J*, *M*, *Q*, *T*). Below a content of 15 per cent. alkali the potash glass has the lower solubility (compare glasses *C*, *F*, *K*, *L*, *N*, *P*, *R*, *S*).

(2) The glasses 188 *E*, *J*, *M*, *Q*, *T*, containing 20 per cent. total alkali, half of which is potash and half soda, have a solubility

much less than either of the corresponding 20 per cent. soda or 20 per cent. potash glasses.* This is a very striking fact, and in order to investigate the matter further the following glasses were melted and their solubilities tested in the usual way.

TABLE VI.

Melt No.	Per cent. SiO_2.	Na_2O.	K_2O.	PbO.
188*F*	65	7·5	7·5	20
H	60	12·5	12·5	15
K	60	7·5	7·5	25
L	60	5	5	30
N	50	7·5	7·5	35
P	50	5	5	40

Table VII gives the solubility of these glasses, together with the solubilities of the corresponding soda (186 series) and potash (187 series) glasses.

TABLE VII.

Set.	Section.	Melt No.	Milligrams H_2SO_4 per 100 gms. glass.	Milligrams alkali.
II. $SiO_2=65\%$	*c*	186*F*	2544	1610
		188*F*	915	728
		137*F*	1214	1169
III. $SiO_2=60\%$	*a*	186*H*	23110	14620
		188*H*	20560	16390
		187*H*	17650	16980
	c	186*K*	2122	1343
		188*K*	711	566
		187*K*	848	816
	d	186*L*	447	283
		188*L*	224	179
		187*L*	208	204
IV. $SiO_2=50\%$	*c*	186*N*	1395	883
		188*N*	572	456
		187*N*	798	768
	d	186*P*	300	190
		188*P*	193	154
		187*P*	163	157

(3) The results obtained bear out those in Table V, and the general statement can be made:—

In alkali–lead–silica glasses where the alkali content is less than 20 per cent., the glass containing both the alkalis in equal proportions by weight will be less soluble than either the glass containing all its alkali as potash or the glass containing all its alkali as soda, no matter what the silica or lead oxide percentage is.

(4) Whether equal proportions by weight of soda and potash

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* Glass 188*B* (10% Na_2O, 10% K_2O, 10% PbO) has a solubility intermediate between the corresponding soda and potash glasses.

give the best results, or whether the two oxides have to be present in proportions other than 1 to 1 to obtain the least soluble glass, has not yet been fully worked out. The best proportion may vary at different concentrations of alkali and according to the amounts of silica or lead oxide present. It is hoped to publish a communication on this matter shortly.

(5) The glasses of any section of a set have a lower solubility than the glasses of the same type in the sections above them, showing that the substitution of lead oxide for alkali improves a glass from the point of view of solubility, whatever the silica content may be. Thus the glass $60SiO_2,15PbO,15K_2O$ has a solubility value of 16980. Substituting 15 per cent. of the potash by 15 per cent. lead oxide lowers the solubility number to 204, eighty times less.

(6) Substitution of silica for alkali in these glasses is as valuable a means of lowering the solubility as the substitution of lead oxide, and is independent of the amount of lead oxide in the glass. This was shown by a study of the solubility numbers of the glasses *S,T, P,Q, L,M, F,J, C,E,H.* Thus the glass $60SiO_2,15PbO,25K_2O$ has a solubility value of 16980. Substituting 10 per cent. of the potash by 10 per cent. of silica lowers the solubility to 1670.

(7) A comparison of the solubilities of the glasses *L, P, S* shows that where the alkali content is 10 per cent., substituting lead oxide for silica lowers solubility.

In the glasses *C, F, K, N, R,* where the alkali content is 15 per cent., the substitution of silica by lead oxide also lowers the solubility.

In the glasses *B, E, J, M, Q, T,* where the alkali is 20 per cent., and in the glasses *A, H,* where the alkali is 25 per cent., the substitution of lead oxide for silica lowers the solubility in the soda glasses when the lead oxide content is less than 40 per cent., and raises the solubility in the potash glasses.

It appears therefore that lead oxide has a greater effect in lowering solubility than silica has, where the alkali content is less than 20 per cent., and the lead oxide less than 40 per cent.

Substitution of lead oxide for silica in the mixed alkali glasses follows the rules for the soda glasses.

(8) In any of these glasses it can be shown that the alkali oxide present governs the solubility far more than either the lead oxide or silica. For example, take a glass of the composition $70SiO_2,15Na_2O,15PbO$. Its solubility number is 1839. Suppose 1 per cent. soda were added to it and the difference in percentage spread equally over the lead oxide and silica. Then the glass $69{\cdot}5SiO_2,14{\cdot}5PbO,16Na_2O$ would have a solubility value 2689, a rise of 850. If 1 per cent. of silica were added and the rise spread

equally, the new glass, $71SiO_2,14{\cdot}5PbO,14{\cdot}5Na_2O$, would have a value 1414, a fall of only 425. Similarly, if 1 per cent. of lead oxide were added the fall would be 430.

5. *Durability and Molecular Composition.*

From the results contained in the tables given previously the following conclusions may be drawn:—

(1) Where potash is substituted molecularly for soda the resultant glass is not so good from a weathering point of view as the original soda glass.

(2) The glasses containing both soda and potash in equivalent molecular proportions are intermediate in their weathering properties between the corresponding soda and potash glasses, being, however, much superior to the potash glasses and only slightly worse than the soda glasses.

(3) Increasing either soda or potash in a glass lowers its durability considerably, whilst an increase of silica or lead oxide improves it.

(4) In the test of exposure to moist air, only the glasses containing less than 14 per cent. of alkali preserve their surfaces unaltered. In the test of exposure for one year only the glasses containing less than 11 per cent. of alkali preserve their surfaces unaltered.

(5) Some of the glasses of these series showed iridescence, being covered with a sheen of colours. This iridescence only appeared on glasses containing a high percentage of lead, and its appearance was dependent to some extent on the amount of alkali present. Thus, when a glass contained more than 15 per cent. of alkali the iridescence occurred when the lead oxide content reached 45 per cent. If the alkali were only 10 per cent., then iridescence did not appear until the lead oxide content was 55 per cent.

(6) The solubility numbers follow the same order as the results of the durability tests, again proving the worth of the solubility of glasses in order to compare durabilities.

Durability and Percentage Composition.

Table VIII shows the results of the weathering tests for glasses the compositions of which are given in Table I. The following points are of interest:

(1) The striking superiority of the glasses containing both alkaline oxides over the corresponding soda or potash glasses from a weathering point of view. This is in line with the results found under the solubility tests, and in general it may be said that the solubility results bear out those obtained under durability.

TABLE VIII.

Set.	Section.	Melt No.	Exposure to moist air for 100 hrs.	Exposure for 1 year to ordinary atmosphere.
I. SiO_2= 70%	*a*	186*A*	Covered with moisture in spots	Badly dulled over. A few white crystals
		187*A*	Covered with layer of liquid	White, hard, opaque film
	b	186*B*	Covered with moisture in spots	Fairly bad spotted film (dry)
		188*B*	Very faint signs of attack	Dulled over
		187*B*	Covered with moisture in spots	Badly dulled over
	c	186*C*	Surface quite bright	Very faint signs of attack
		187*C*	A few wet spots	Dulled over
II. SiO_2= 65%	*b*	186*E*	Covered with moisture in spots	Badly dulled over all surface
		188*E*	Very faint signs of attack	Faintly dulled
		187*E*	Covered with moisture in spots	Very badly dulled
	c	186*F*	Surface quite bright	Very faintly dulled
		187*F*	A few wet spots	Faintly dulled
III. SiO_2= 60%	*a*	186*H*	Covered with spots of moisture	Badly dulled
		187*H*	Covered with liquid blotches	Very badly dulled
	b	186*J*	Spots of liquid	Fairly badly dulled
		188*J*	Bright surface	Bright
		187*J*	Spots of liquid	Badly dulled
	c	186*K*	Bright surface	Very faintly filmed
		187*K*	Slight signs	Faintly filmed
	d	186*L*	Bright surface	Bright surface
		187*L*	,,	,,
IV. SiO_2= 50%	*b*	186*M*	Very small spots of liquid	Bad film and white spots
		188*M*	Bright surface	Faintly filmed
		187*M*	Slightly spotted with liquid	Very bad film. Semi-opaque
	c	186*N*	Bright surface	Very faint signs of filming
		187*N*	Very slight signs of attack	Faint film
	d	186*P*	Bright surface	Bright surface
		187*P*	,,	,,
V. SiO_2= 40%	*b*	186*Q*	A few spots of liquid	Bad filming in spots
		188*Q*	Bright surface	Very slight film
		187*Q*	Very slightly spotted	Very bad film. Semi-opaque
	c	186*R*	Bright surface	Dull film, signs of iridescence
		187*R*	Very slight signs	,,
	d	186*S*	Bright surface	Bright surface
		187*S*	,,	,,
VI. SiO_2= 30%	*b*	186*T*	Covered with spots of liquid	Spotted surface. Iridescent
		188*T*	Bright surface	Very slight film. Iridescent
		187*T*	Quite wet surface	Opaque film

(2) A study of the glasses in a set show that where the silica remains constant the substitution of lead oxide for alkali improves durability.

(3) The results for the glasses *L*, *P*, *S* and *C*, *F*, *K*, *N*, *R* show

that where the alkali remains constant and is below 15 per cent. the substitution of silica by lead improves durability. Where the alkali is constant and greater than 20 per cent. (glasses *B*, *E*, *J*, *M*, *Q*, *T* and *A*, *H*), the substitution of lead oxide for silica lowers the durability, when the lead oxide is more than 20 per cent. Thus the glass $50SiO_2,20K_2O,30PbO$ after one year's exposure is covered with a semi-opaque skin, whilst the glass $70SiO_2,20K_2O,10PbO$ is only badly dulled over.

(4) The substitution of silica for alkali, the lead oxide remaining constant, improves the durability.

(5) In the case of the soda glasses, those with a soda percentage less than 15 per cent. remain unaltered under the moist air test. Only those potash glasses containing 10 per cent. or less are unaltered by this test. In the case of the "mixed" alkali glasses no filming takes place until the alkali reaches 20 per cent.

(6) In the exposure test of one year only glasses containing 10 per cent. of alkali remained unaltered where only one alkali is present. Where the mixed alkalis are present, up to 15 per cent. can be added without surface attack.

(7) A comparison of the results of Table VIII with those of Table V shows that those soda glasses with a solubility number less than 2000 remain bright under the one hundred hours' exposure test to moist air. Potash glasses with a solubility number as low as 800 are affected by this test, but a potash glass as low as 200 is not affected.

In the exposure test for one year only the alkali glasses with a solubility number less than 300 are unaffected.

(8) Iridescence shows up with an alkali content of 15 per cent. when the lead oxide content is 45 per cent. With 10 per cent. of alkali no iridescence was observed with a lead oxide content of 50 per cent.

(9) It will be seen that the use of either alkali alone in the manufacture of lead glasses is to be deprecated where high durability is desired. The best percentage proportion by weight of soda to potash has yet to be properly investigated, but the results obtained already show the value of equal proportion by weight of the two alkaline oxides in improving durability.

(10) It is evident that two different types of weathering have to be distinguished in dealing with lead glasses. First of all, there is the weathering due to the presence of alkali which shows itself in the form of wet or dry filming and wet or dry "spottiness." Then there is the weathering due to a high lead oxide content which shows itself in the form of iridescent filming. This latter type of weathering may be due to accidental impurities in the atmosphere,

such as sulphur compounds, and investigation is proceeding on this point.

6. *Pot Attack.*

(1) Examination of pots after melting showed that when the percentage of alkali in a glass was increased there was a more severe pot attack. Thus in a series of soda glasses or in a series of potash glasses the colour of the glasses became worse as the alkali content increased. Since the colour was due to iron compounds chiefly absorbed from the pot clay, the deeper the colour the greater was the pot attack.

(2) In every case, whether considered from the point of view of equimolecular proportion or of equal percentage proportion by weight, the potash glass had less colour and was more brilliant than its corresponding soda glass.

(3) Increasing the lead oxide in a series of glasses always caused an increase in pot attack, and so the colour of the glasses tended to deepen as the lead oxide increased. With proportions of lead oxide as high as 60 per cent., the attack on pot clay is very vigorous, and if the temperature of such a melt were much above 1250° the pot would be eaten right through ($\frac{1}{4}$ inch to $\frac{1}{2}$ inch of pot clay) in an hour or so by the molten metal.

(4) When the lead oxide content is greater than 50 per cent. the glass begins to assume a yellow colour, which seems inherent to heavy lead oxide glasses. It is easily distinguished from the yellow colour sometimes imparted by iron compounds.

(5) Fortunately, increasing the lead oxide content of a glass lowers its melting point considerably, and so glasses containing large proportions of lead oxide can be melted at comparatively low temperatures, so minimising the danger of pot attack, with subsequent deterioration of the glass and danger to the pot.

(6) It may be noted here that, weight for weight (up to 25 per cent. as far as has been investigated), lime is a better flux than lead oxide.

General Summary and Conclusions.

(1) Comparisons have been made of several properties of glass of the type $100SiO_2,yR_2O,xPbO$, where R_2O may be Na_2O,K_2O or equimolecular Na_2O,K_2O mixtures, y varying between 20 and 40 molecules and x between 5 and 40 molecules.

(2) Further, a series of glasses containing equal percentage quantities of soda and potash has been investigated. In this series several sets of glasses have been studied, the silica, lead oxide, and alkali being kept constant in turn and the other oxides varying.

(3) *Density.*—(*a*) The glasses of the molecular series

$$100SiO_2,40Na_2O,xPbO$$

and $100SiO_2,20Na_2O,xPbO$ are all higher in density than those of the corresponding potash glasses.

(*b*) The glasses of the molecular series

$$100SiO_2,20Na_2O,20K_2O,xPbO$$

and $100SiO_2,10Na_2O,10K_2O,xPbO$ have densities intermediate between those of the corresponding soda and potash series.

(*c*) Comparing the relative effect of equal percentages of soda and potash, the other oxide percentages being the same, the soda glass has the higher density.

(*d*) When half of the percentage weight of soda in a glass is substituted by potash, the resultant glass has a density intermediate between the glasses containing soda and potash alone.

(*e*) The following constants have been found to represent increase of density with variation of composition:

$+1\%$ PbO $-$ 1% of Na_2O (silica constant) $=$ 0·020
$+1\%$ PbO $-$ 1% of K_2O (silica constant) $=$ 0·020

$+1\%$ PbO $-$ 1% of SiO_2 (soda constant) $=$ 0·028
$+1\%$ PbO $-$ 1% of SiO_2 (potash constant) $=$ 0·028

$+1\%$ PbO $-$ $\frac{1}{2}\%$ of SiO_2 $-$ $\frac{1}{2}\%$ of Na_2O $=$ 0·024
$+1\%$ PbO $-$ $\frac{1}{2}\%$ of SiO_2 $-$ $\frac{1}{2}\%$ of Na_2O $=$ 0·024

Thus the addition of 1 per cent. of lead oxide to a glass of the type

$$aSiO_2,bR_2O,cPbO,$$

where $a=30$ to 70 per cent., $b=10$ to 25 per cent., and $c=5$ to 50 per cent., and $(a+b+c)=100$ per cent., results in a rise in density of 0·024, whether R_2O is represented by soda or by potash, when the subsequent 1 per cent. fall is shared equally by the silica and alkali.

(4) *Refractive Index.*—(*a*) From the point of view of equimolecular proportions, the potash glasses of both the

$$100SiO_2,40R_2O,xPbO$$

and $100SiO_2,20R_2O,xPbO$ series have a slightly higher refractive index than the corresponding soda glasses. This is the reverse of the behaviour of the oxides in the case of density, where the soda glass has the higher density. The difference in η_D for the soda and potash glasses is, however, very small, and the lead oxide plays the most important part in determining the refractive index of these glasses.

(*b*) In the molecular series of glasses the potash glass has a slightly higher total dispersion than its corresponding soda glass.

(*c*) The glasses of the $100SiO_2,20Na_2O,20K_2O,xPbO$ and

$$100SiO_2,10Na_2O,10K_2O,xPbO$$

series are intermediate in η_D and $(\eta_F - \eta_C)$ between their corresponding soda and potash glasses.

(*d*) Weight for weight, the soda glass has the higher refractive index for the *D*-line and the higher total dispersion. As the amount of alkali in a series of glasses increases, the difference in η_D and total dispersion between the soda glasses and their corresponding potash glasses decreases.

(*e*) The following constants have been found:

	Increase in η_D.	Increase in $(\eta_F - \eta_C)$.
+1% of PbO − 1% of Na_2O (silica constant)	0·0010	0·00012
+1% of PbO − 1% of K_2O (silica constant)	0·0014	0·00012
+1% of PbO − 1% of SiO_2 (soda constant)	0·0034	0·00026
+1% of PbO − 1% of SiO_2 (potash constant)	0·0034	0·00026
+1% of PbO − ½% of SiO_2 − ½% of Na_2O	0·0022	0·00019
+1% of PbO − ½% of SiO_2 − ½% of K_2O	0·0024	0·00019

(5) In the alkali–lead oxide–silica glasses soda is a better flux than potash when added in equivalent amount by weight.

(6) In corresponding soda and potash glasses, the one containing soda has the lower melting point.

(7) *Devitrification* is more easily induced in the soda–lead glasses than in those containing potash only. Glasses of the silica–lead oxide–soda type tend to deposit silica when the silica content is greater than 60 per cent. No glasses up to a content of 50 per cent. lead oxide tend to deposit lead silicate.

(8) *Solubility.*—(*a*) The solubility of the glasses of the molecular series $100SiO_2,40Na_2O,xPbO$ and $100SiO_2,20Na_2O,xPbO$ is less than that of the corresponding potash glasses.

(*b*) From the point of percentage composition by weight, the soda glasses are less soluble than the potash glasses when the alkali content is greater than 20 per cent. Below this 20 per cent. the potash glasses are the less soluble.

(*c*) A mixture of equal percentages of soda and potash has a remarkable effect upon solubility. Below a total alkali content of 20 per cent., a glass containing equal percentages of both soda and potash has a much lower solubility than a glass containing the same amount of alkali in the form of soda or potash alone.

(9) *Durability.*—(*a*) From the equivalent molecular point of view, the soda glasses are superior in durability to the corresponding potash glasses, whilst the glasses containing both oxides in equivalent molecular proportions are intermediate in their weathering properties.

(*b*) From the point of view of equal percentage weight, the soda glasses show up best under weathering tests until an alkali percentage below 15 per cent. is reached. Then the potash glasses appear equal to the soda glasses for durability.

(*c*) The glasses containing equal percentage weights of soda and potash are far superior to either of the corresponding soda and potash glasses.

(*d*) When the lead oxide content is greater than 45 per cent., the glasses may become iridescent upon an otherwise bright surface.

(10) Considering the whole of the glasses from the points of view (1) of general use, (2) of optical use, the following remarks have to be made:

(*a*) No glass in the molecular series $100SiO_2,40R_2O,xPbO$ is of use either optically or otherwise owing to its bad weathering properties. The best glass is $100SiO_2,40Na_2O,40PbO$ (SiO_2, 34·6 per cent.; Na_2O, 13·8 per cent.; PbO, 51·6 per cent.), and this tends to become dull and iridescent on long exposure.

(*b*) In the molecular series $100SiO_2,20R_2O,xPbO$ the glasses capable of use, judged by the solubility classification,* are as under:

Class I.

(1) $100SiO_2,20Na_2O,30PbO$.
(2) $100SiO_2,20Na_2O,40PbO$.
(3) $100SiO_2,10Na_2O,10K_2O,30PbO$.
(4) $100SiO_2,10Na_2O,10K_2O,40PbO$.
(5) $100SiO_2,20K_2O,40PbO$.

Class II.

(6) $100SiO_2,20Na_2O,15PbO$.
(7) $100SiO_2,20Na_2O,20PbO$.
(8) $100SiO_2,10Na_2O,10K_2O,15PbO$.
(9) $100SiO_2,10Na_2O,10K_2O,20PbO$.
(10) $100SiO_2,20K_2O,30PbO$.

Class III.

(11) $100SiO_2,20K_2O,20PbO$.

Actual exposure tests bear out these classifications, except in the case of the potash glasses. Under the actual exposure test, even the $100SiO_2,20K_2O,40PbO$ glass is badly dulled over, although placed in Class I by the solubility test. From this it would appear that the solubility test as a criterion for the durability of potash–lead–silica glasses must be modified.

Of the above list, therefore, only the soda and mixed alkali glasses should be used. They all contain less than 15 per cent. of alkali and less than 60 per cent. of silica. Thus they will be free from devitrification troubles. All are easily melted in the ordinary glass furnace, and any one of them could be employed for optical work if the refractive indices were desired. The optical constants range from 1·56 to 1·66 for η_D and from 42 to 33 for ν value, and the densities from 3·15 to 3·95.

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* See this vol., TRANS., p. 39.

If it were desired to use a purely potash glass, owing to the higher brilliance of potash–lead glasses over the soda–lead glasses, then less potash would have to be put into the batch than is represented by the above two formulæ, $100SiO_2,20K_2O,40PbO$ ($K_2O=11$ per cent.) and $100SiO_2,20K_2O,30PbO$ ($K_2O=13$ per cent. approx.).

The percentage compositions of the soda and the mixed alkali glasses in Classes I and II above are as under. Any glasses between the limits of the oxide percentages shown will be satisfactory glasses from the point of view of melting properties, weathering properties, colour, and freedom from devitrification tendencies. The numbers refer to glasses in the preceding list.

Class I.

(1) SiO_2, 43. Na_2O, 8·5. PbO, 48·5.
(2) SiO_2, 37. Na_2O, 7·5. PbO, 55·5.
(3) SiO_2, 42. Na_2O, 4·5. K_2O, 6·5. PbO, 47.
(4) SiO_2, 36·5. Na_2O, 4. K_2O, 5·5. PbO, 54.

Class II.

(6) SiO_2, 57. Na_2O, 11. PbO, 32.
(7) SiO_2, 51. Na_2O, 10. PbO, 39.
(8) SiO_2, 55. Na_2O, 5·5. K_2O, 8·5. PbO, 31.
(9) SiO_2, 50. Na_2O, 5. K_2O, 8. PbO, 37.

It will be seen that in order to get a first-class glass of the alkali–lead oxide–silica type, the alkali percentage must not rise above 10 per cent. if a single alkaline oxide is present, and must not rise above 11 per cent. when both oxides are present. In order to avoid devitrification troubles, the silica content must be kept below 60 per cent., and the lead oxide percentage should be greater than 30.

The following would be the percentage compositions of first-class lead glasses containing only potash as the alkaline oxide. Any glasses of intermediate composition would, of course, be first-class glasses:

SiO_2, 44. K_2O, 8. PbO, 48.
SiO_2, 37. K_2O, 7. PbO, 56.

(*c*) Turning now to the glasses worked out according to their equivalent weight percentages, the following glasses are capable of use, judged from the point of view of durability and freedom from devitrification tendencies. The numbers represent percentage weights, and it must be understood that any glasses in the near vicinity of those mentioned will be similar in properties. Only glasses up to 50 per cent. of lead oxide have been investigated.

Class I.

$50SiO_2,10Na_2O,40PbO$.
$50SiO_2,10K_2O,40PbO$.
$40SiO_2,10Na_2O,50PbO$.
$40SiO_2,10K_2O,50PbO$.
$60SiO_2,5Na_2O,5K_2O,30PbO$.
$50SiO_2,5Na_2O,5K_2O,40PbO$.
$40SiO_2,5Na_2O,5K_2O,50PbO$.

Class II.

$60SiO_2,10Na_2O,30PbO$.
$60SiO_2,10K_2O,30PbO$.

Class III.

$50SiO_2,7\frac{1}{2}Na_2O,7\frac{1}{2}K_2O,35PbO$.

Class IV.

$60SiO_2,7\frac{1}{2}Na_2O,7\frac{1}{2}K_2O,25PbO$.

Class V.

$40SiO_2,15Na_2O,45PbO$.
$40SiO_2,15K_2O,45PbO$.
$50SiO_2,15Na_2O,35PbO$.
$50SiO_2,15K_2O,35PbO$.
$65SiO_2,7\frac{1}{2}Na_2O,7\frac{1}{2}K_2O,20PbO$.

From the above list it will be seen that where a glass containing a single alkaline oxide (either soda or potash) is in a certain class, substitution of half of that alkaline oxide by the other alkaline oxide raises the glass in durability at least one class. Thus the glass $60SiO_2,10Na_2O,30PbO$ is in Class II, but the glass $60SiO_2,5Na_2O,5K_2O,30PbO$ is in Class I. This fact has an important bearing on the manufacture of optical glasses. For suppose a glass were required of $\eta_D = 1{\cdot}53$ and $\nu = 49$. It would be impossible to make a durable glass of these constants using only soda or potash as alkaline oxide, but the glass $65SiO_2,7{\cdot}5Na_2O,7{\cdot}5K_2O,20PbO$ would be in the neighbourhood of these constants and possibly durable enough, although only in Class V. Special care in melting would have to be taken to prevent devitrification.

To manufacture first-class optical glasses of the alkali–lead oxide–silica type is not possible below a refractive index for the *D*-line of 1·55 and above a ν value of 43, and then only by using both alkaline oxides. When " flint " glasses of first-class durability and η_D values below 1·55 are required, special means of ensuring durability have to be taken by modifying the batch, new oxides being added.

The fact seems established therefore that no really satisfactory alkali–lead oxide–silica glass can be made containing much more than 60 per cent. of silica, owing to fear of devitrification, and more than 15 per cent. of alkaline oxide, owing to fear of lack of durability. Indeed, for first-class glass not more than 10 per cent. of alkali can be used, and if possible this should be in the form of both soda and potash.

(*d*) It should be noted that a glass of the type corresponding to the Benrath formula, $6SiO_2,1R_2O,1PbO$, would be in Class II from a weathering point of view if R_2O were represented by soda ($56SiO_2,10Na_2O,34PbO$), and in Class V if R_2O were represented by potash ($53SiO_2,14K_2O,33PbO$). Thus it cannot be said that the Benrath formula is the one representing the best alkali–lead–silica glass. The molecular formula $5SiO_2,1R_2'O,1R''O$ suggested by the author as being best for the alkali–lime–silica glasses is better than the Benrath formula for the alkali–lead–silica glasses, in that it places the soda glass in Class I for weathering. The potash glass, however, remains in Class V, and so this $5SiO_2,1R_2O,1PbO$ formula cannot be considered satisfactory.

From a solubility point of view, the molecular formula, $6SiO_2,1R_2O,2PbO$, is best, as it places both the soda and the potash glasses in Class I from a weathering point of view. However, such glasses would be soft,* easily scratched, inclined to be slightly coloured, and liable to become iridescent under certain atmospheric conditions.

It seems, therefore, impossible to hit upon a formula for an alkali–lead–silica glass which shall be entirely satisfactory. In the author's opinion, the best molecular formula is $5SiO_2,1R_2O,1{\cdot}5PbO$, as the glass made based upon this formula will satisfy most of the conditions of colour, brightness, durability, melting, and working desired by the manufacturer. The soda glass and the mixed alkali glass of this type would be in Class I for weathering, the potash glass in Class II. The oxide percentages would be in round numbers:

(1) $43SiO_2,8{\cdot}5Na_2O,48{\cdot}5PbO$.
(2) $41SiO_2,12{\cdot}5K_2O,46{\cdot}5PbO$.
(3) $42SiO_2,4{\cdot}5Na_2O,6{\cdot}5K_2O,47PbO$.

The potash glass would be the most brilliant and colourless, but the least durable. The mixed alkali glass would be very brilliant and durable. The constants for the glasses would be approximately:

(1) Na_2O glass ……	η =1·630,	ν=35·5.	Density	=3·75	Solubility	Class	I.
(2) K_2O glass ……	=1·628,	ν=35·0.	,,	3·65	,,	,,	II.
(3) Na_2O,K_2O glass	=1·628,	ν=35·3.	,,	3·68	,,	,,	I.

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* It should be noted that as the percentage of lead oxide in glass increases it becomes softer and more easily scratched.

(*f*) Several of the glasses worked out are identical, or nearly so, in their properties with well-known optical glasses. Thus the two glasses 100molsSiO_2,20Na_2O,30PbO and 100molsSiO_2.20Na_2O,40PbO are very near in their properties to two well-known Schott glasses, namely, 0·93 and 0·102, as will be seen from the following table.

TABLE.

Glass.	Density.	η_D.	$\eta_F - \eta_C$.	ν.
100SiO_2,20Na_2O,30PbO ...	3·69	1·6272	0·01767	35·5
Schott, 0·93...............	3·68	1·6245	0·01743	35·8
100SiO_2,20Na_2O,40PbO ...	3·94	1·6571	0·01984	33·1
Schott, 0·102	3·87	1·6489	0·01919	33·8

Slight alterations in the two glasses, which could be calculated from Tables VI—IX in paper VI, would give glasses identical in constants with 0·93 and 0·102, for example, altering 100SiO_2,20Na_2O,40PbO to 100SiO_2,21Na_2O,37PbO should give η_D= 1·6490, $\eta_F - \eta_C$ 0·01917, $\nu = 33·85$; density = 3·88; values almost identical with the values of Schott, 0·93. These values, of course, would not be given except on small-scale meltings, and further modifications would have to be made to the batch to obtain them on a large scale.

The substitution of some potash for soda would be beneficial to the two glasses, as it would improve brilliance and durability. The alteration in the batches due to this substitution could be worked out from the values given in the various papers, so as to preserve the constants as above.

The author desires to thank the Directors of Messrs. Wood Bros. Glass Co., Ltd., and of the Derby Crown Glass Co., Ltd., for permission to publish the foregoing researches. He also desires to express his thanks to Mr. Frank Wood, C.B.E., B.Sc., F.I.C., and also to his colleagues at Derby and Barnsley, for their help, criticism, and advice.

For the splendid series of photomicrographs the author is indebted to Mr. Walter Morritt, of the Derby Crown Glass Co., Ltd., who has spared no pains to make this section of the work a success.

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XXXI.—*Lessons from the Visit to America.*

(*Report of the Sheffield Meeting, October 20th*, 1920.)

Mr. W. Butler, from the Chair, said the audience was present to welcome the Pilgrims home from their trip to see the wonders of America. He had heard from some of the members of the party how hospitably they had been received, and it was now their pleasure to listen to some of their experiences.

The first speaker was Prof. W. E. S. Turner, who opened by saying that the anticipations which they had entertained for more than twelve months had now been realised. With great hopes, the party, numbering thirty-two, set out for America on August 14th, and he thought he could say, in a general way and for the entire party, that their hopes had been amply fulfilled—in fact, more than fulfilled.

Prof. Turner said he preferred to direct any remarks he might make towards helping those members of the Society who were unfortunately unable to take part in the trip to appreciate the atmosphere in which the party had worked and moved for a period of about a month. It would be remembered that they had intended originally to sail on August 14th by the Anchor liner "Columbia," but about three weeks before that boat was due to sail she was put back into dock for slight repairs. Through the good offices of Messrs. Thos. Cook and Sons, however, they were able to get transferred, with very little inconvenience beyond the filling up once more of those terrible passport forms, to the Furness-Withy liner, "Fort Victoria," and the ultimate result was, he thought, very much to their advantage. They set out from Liverpool, and were given a hearty send-off by Prof. Boswell and Mr. Connolly, two of their Vice-Presidents, and quite a number of other friends. They arrived in Boston after what was considered for that particular boat a record trip. Their first day was spent in sight-seeing, but this did not mean that the time was ill-spent, for there was a certain amount of special interest in visiting one of the museums in Boston, where they inspected a splendid collection of models of flowers, built up of innumerable threads of glass fibre, woven most intricately and deftly into floral forms, as well as sections of them, so as clearly to show their structure. In this manner their glass experience could be said to have begun immediately upon their arrival in Boston.

The party left Boston by the night boat for New York, where they were met on arrival by the local committee of the American Ceramic Society. Already, two days before landing, they had received two wireless messages, one from the headquarters of the Glass Division of the American Ceramic Society extending kindest greetings and assuring them of a hearty welcome, the other from the New York Committee. In the afternoon the New York Committee brought along a fleet of motor-cars and took the visitors for a two hours' drive round the city, not omitting to take them up the famous Woolworth tower. Afterwards they were entertained to dinner on the roof garden of the Hotel Waldorf-Astoria, where they encountered a " spread " which was indicative of the largeness and generosity of the hospitality they were subsequently to meet. Later in the evening they were taken to the " Biggest Show on Earth " at the New York Hippodrome.

On the morning of the following day, August 25th, the party was divided up into three groups. One group paid a visit to the factory in New Jersey of the Westinghouse Electric Lamp Co., where they were met by Dr. Brann and others. This experience, he thought, could be summed up very well in the expression of one member of the party, who said that the visit had been a revelation, the whole factory appealing to one just as though it had been set out at the Crystal Palace on exhibition. The second party was driven about Brooklyn and hustled through a series of works, in which they were able to see, amongst other things, the automatic cutting of glass moulds by machinery. The third section of the party—the ladies—was taken on a shopping expedition.

On the same day the reassembled party was taken on to Vineland, in New South Jersey. En route they were met by a deputation, prominent amongst whom was Mr. Herbert A. Walls. Vineland held very many happy memories for the whole of them, for they were treated there most hospitably. They saw, amongst others, the works of the Kimble Glass Co., which he thought one might rightly say was, in its own particular line, the leading glassworks of the world. It was a factory devoted very largely to lamp-worked articles, scientific apparatus, and chemical glassware. The raw material, consisting of tubing, was made on the spot by the Libby Owens tube-drawing machine, and this was the only place at the moment where that machine was continuously fed from a tank furnace, in order that the operation could go on day in and day out for a whole year, providing the tank remained in operation and the machine did not break down. Visits were also paid to the Minotola Glassworks, making bottles by machinery; the Vineland Flint Glass Works, making chemical and scientific glassware of various kinds;

the Durand-Koering Glass Co., also making chemical glassware. The time in the Vineland district passed all too rapidly.

On the evening of the day following arrival in Vineland the party was banqueted; he wished he could convey to them some idea of that banquet. Vineland was not a large place, although it ranked as a city, like many other American places with 2,000 inhabitants or more. Its chief hotel would comfortably accommodate at an ordinary luncheon or dinner from fifty to sixty people. The party numbered seventy, plus a jazz band, which, he might add, was quite as important a feature as the other part of the function.

From Vineland the party moved on to Philadelphia and Pittsburgh. Dr. Tillotson, the Secretary of the Glass Division of the American Ceramic Society, who had met them in New York, had taken the skeleton outline which had been provided of the trip the party desired to make, and along with his friends had hammered out a course of travel even more extensive than the one originally planned. Special travel tickets, reserved sleeping cars, and the like, had been arranged, and the prospects of a regular hustling American trip lay before them.

On arrival at Pittsburgh, from the Saturday onwards for a week, their time was very fully occupied. In connection with this part of the trip special tribute must be paid, not only to Dr. Tillotson, but also to another gentleman whose personality and influence stood very high in the glass trade of the New Continent—Mr. H. L. Dixon —who had made arrangements with no fewer than six clubs in the city of Pittsburgh to enrol them as honorary members during their stay.

In the course of a sixty-mile drive round the city of Pittsburgh they had an opportunity of forming impressions of its geographical location and its industrial importance. They found that in some ways there were certain marked parallels between Sheffield and Pittsburgh, both industrially and in its geographical relationship to the surrounding country. During the week there was scarcely a day when they were not invited to some luncheon provided by one or other of the glass factories of the neighbourhood. They visited two or three, sometimes more, works in a single day, and the pressure of their engagements, as well as the interest which was incidental thereto, was intense.

The record of their adventures from Pittsburgh onwards would need to be taken up by some other members of the party, for he (Prof. Turner) did not proceed with the party beyond Pittsburgh, but journeyed north in order to transact other business, subsequently rejoining the party at Montreal. He would, however, like to say one or two things with regard to the visit to Pittsburgh and the outcome of their stay there. He was not going to refer to lessons learned in the glass works. His impressions in this direction had previously been recorded extensively in an article in the Journal under the heading of "The Glass Industry of North America." He would like to say, however, that a great part of his experience and his happiness in connection with the tour was in watching the faces of those who had made the trip for the first time, and noting their surprise and admiration for some of the things they saw. "America is a land of ideas," continued Prof. Turner, "and it is a land where they are not afraid of putting into practice the many ideas which they have, and of trying them out." Mr. Libbey, whom he had met in London quite recently, had expressed the opinion that probably not more than ten per cent. of these ideas ever entirely succeeded. It was certain, however, from what they saw during their visit, that the ten per cent. which proved successful more than paid for the loss which might be sustained in experimenting upon the remaining ninety per cent.; for there was no doubt about it that the glass industry in America was in an exceedingly flourishing condition. It was not only vigorous, but it had gained a self-confidence which he would like to see emulated in Great Britain. There was, at the moment, no feeling that the American glass industry would go back; rather was it thought that it would continue to press forward in all directions.

Fortunately for America, there was no lack of money in that country. One realised, after a war such as that through which we had recently passed, the tremendous handicap under which we in England were working through lack of capital. In America that handicap did not appear to exist. Bankers were much more willing to support financially any really enterprising person who was starting out in industry, and who had determination and a small credit with which to commence. One might wish that those advantages were available in this country, for they would stimulate the glass trade very considerably.

Of other lessons there were several. One of these was the intense good feeling which existed between the true American and the people of the United Kingdom. It was explained to them on more than one occasion that in America a man who truly realised the benefits of American citizenship had no time to take up the hyphen; he was never an Irish-American or a German-American. He was an American out and out. The true Americans left no doubt in their minds as to the cordiality of the feeling which they had for Britishers, and the preference which they would give the Britisher for trade under all conditions which made it possible for them to trade with Britain. In all the larger movements of life which affected the well-being of humanity, the Americans would wish our friendship more than that of any other country. This was not only made evident in the speeches that were made, but in the cordiality of the handshakes and the personal and individual expressions of goodwill. He (Prof. Turner) had returned once again from America determined that if in any way he could help to stimulate and strengthen the ties of that friendship it should be done.

Whilst in America, two joint meetings of the contemporary societies were held at which scientific and technical matters were discussed. Unfortunately, the programme was a little too crowded on both occasions, and the discussion was not so stimulating as it might otherwise have been. Certain arrangements were made with a view to forging the links uniting the two Societies. For one thing, they left behind with their American friends a specification which they desired American investigators to consider, and upon which their views would be appreciated. They also left behind a paper, by Dr. C. J. Peddle, on the nomenclature of glasses, and they hoped in due course to receive the report of the committee which was about to consider it. They brought back with them a series of recommendations framed by the American Ceramic Society on refractory materials and standards, which it was intended to discuss and report upon, and there were sundry other matters which were discussed between the Secretary of the American Ceramic Society and himself calculated to promote harmonious and concerted working. There was also a mutual exchange of membership between the two Societies.

Lastly, the invitation which the Society of Glass Technology commissioned the delegates to extend to their American friends was duly delivered at the official banquet which the Glass Division of the American Ceramic Society gave them—a banquet which the American Ceramic Society themselves looked upon as highly important, and which was consequently attended by the leading civic representatives of the city and district, as well as by the president of the Pittsburgh Plate Glass Co., one of the largest industrial organisations within a very large radius of Pittsburgh, the Chancellor of the Pittsburgh University, and other eminent persons. It was quite evident that a large number of the members of the American Ceramic Society intended to become members of the party which was to visit England in 1922. That meeting he looked forward to with pleasurable anticipation, and he was sure that when the time arrived they would receive their American friends, both collectively and individually, with a warmth of welcome no less hearty than had been theirs in America.

There was one lesson which concerned intimately all those who made the trip to America. He (Prof. Turner) not only regarded the journey as having accomplished much in the direction of strengthening the ties between the two countries and the kindred societies, but also in weaving a network of friendships which would become stronger throughout their own Society. They had learned to know one another a great deal better during that six weeks' voyage, and they realised now, if they had not fully realised it before, that they had interests in common. They believed that, as a result of the visit, they could expect, at all times of adversity, strength and support from one another. He believed that in those thirty or more members who journeyed out together to America they would have a nucleus of strength and solidarity which would be of the greatest assistance in negotiating the future progress of the Society of Glass Technology.

Mr. W. J. Rees said that his interests in America lay in what might be considered to be a branch of the glass industry. His attention was chiefly devoted first of all to the production and utilisation of sand, and, secondly, to glass refractory materials. So far as the glass industry itself was concerned, his impressions of the visits to works were a trifle mixed. In some ways he was immensely surprised, despite what he had been led to expect, at the activity of the American glass industry. For a much longer time than with us, the American manufacturer had been up against the problem of high labour costs, and consequently for quite a number of years the engineers of the glass industry there had been devoting the whole of their efforts to the utilisation of mechanical means of production. It was in this respect that the Americans had made greater advances than the glass manufacturers of this country. In America, if a thing could be done by machinery it was rarely done by hand labour.

Another thing which surprised him was the enormous scope of the market which the Americans must have, both at home and abroad. The output of the smaller varieties of glassware was tremendous. It almost passed comprehension as to what became of all the ware that was produced. A great deal of it was what we in this country would not consider good; but it was good enough for its purpose, and from the Americans' point of view this was what seemed to count most. They did not devote a lot of time to unnecessary trimming. Such things as food containers, for instance, were just sufficiently well finished to serve their purpose, and that was all.

A further point which was noticeable in visiting some of the American glass works was they were no better than those in this country in obliterating rubbish from the factory. Many of the

English glassworks were admittedly an eyesore in this respect. One found, lying all over the place, piles of cullet, heaps of disused bricks, and so on. The Americans were just as bad. There were, it was true, a few works which were almost like drawing-rooms in their tidiness, but the average glass factory could not be included in this category. The general organisation of the factories, however, struck him as being very good indeed. There was very little waste time, either in dealing with the raw materials in the actual glassmaking, or in dealing with the finished glass. In this respect he thought they had much to learn from their American friends. The general organisation of their works was undoubtedly good. There was certainly very little waste labour.

So far as the raw materials were concerned, the American manufacturers were in a better situation than those in this country. Nearly all the American glass sands were obtained, as they had been told a year ago by Prof. Boswell, by the crushing of sandstone rocks. The crushing was performed by very efficient machinery, and the crushed material was sifted, washed, and almost invariably dried. The sands were transported generally in covered box wagons, capable of carrying some 50 tons of sand. By this means the sand was delivered to the glass factory in a clean and useful condition. There was very little loss *en route;* no dirt got into the sand, and the material that was delivered to the glass works was consequently of uniform silica content. The mixing machinery was consistently good. The most outstanding mixing plant he himself had seen was that at the works of the American Window Glass Company, where there was a most efficient and economical mixer for dealing with very large quantities of raw materials for the batch. He would imagine that it would be well worth the while of any British glass manufacturer who was concerned with a large production, and who used big quantities of batch, to take a trip across to America to see that one unit alone. The thoroughness with which the problem of storing and mixing batch had been tackled by the company to which he had referred was most impressive. The visitors were also able to see there a very large tank furnace, about 130 feet long by 35 feet wide and 5 feet deep, capable of holding somewhere about 1,300 tons of molten glass. The furnace referred to was employed in the melting of glass to be used for automatic cylinder drawing. The quality of the glass at the time of the visit was perhaps not all that it might have been, but from an inspection of the ware in the cutting-rooms and store-rooms it was clear that the average quality was good.

In regard to refractories, he was bound to say that he did not think that we in this country had very much to learn from America.

The average life of such things as glasshouse-pots, tank blocks, and so on, was very much the same as in our own country. The Americans had certainly adopted most careful methods in the making and storing of both pots and tank blocks. It was noticeable that the majority of the glasshouse-pot makers did not rely upon their own resources of raw clays; if they found that a mixture of clays from various sources gave a better result than could be obtained from mixtures of their deposits of clay, they did not hesitate to import clays from other States. Two or three of the biggest organisations making glasshouse-pots used clays from three or four different raw clay sources. It was very interesting to find that by a proper examination and utilisation of their domestic raw clays the Americans had been able to discover mixtures for the making of glasshouse-pots which had superseded almost entirely the Grossalmerode clay upon which they had relied in pre-war days upon Germany.

In addition to the careful choice and mixing of fireclays, it was interesting to find that the American glass manufacturers were now devoting a great deal of attention to the casting of glasshouse-pots. One company in particular had acquired the services of a member of the staff of the Bureau of Standards who had been responsible for a great deal of the casting work undertaken by the Bureau during the war. Nearly all the pots used in the manufacture of American optical glass were, during the later stages of the war, produced by casting, a pot batch being used which imparted almost a porcelain body to the pot. Investigational work was being carried on with the view of developing a casting process which would give a satisfactory cast pot from the ordinary clays now being used for the hand-made pots. The American hand-process of building pots was practically identical with the process used in Great Britain, and the shapes and sizes of the pots were very much the same. There were one or two small differences. In the larger covered pots, for instance, the makers arranged in the front of the bonnet of the pot two holes about three or four inches in diameter, from which they could take trial proofs without removing the stopper of the pot. This arrangement struck him as being a good one, and so far as he knew it had not been generally adopted in this country.

In the manufacture of tank blocks, mixtures of clays were almost invariably used—those particular mixtures which, after extensive trials, had been found to give the best results for a particular purpose. The Americans went in very largely for making special compositions of clays for blocks to be used in particular parts of the furnace; for instance, for the bottom and side-blocks of a tank they would use one particular batch; another batch would be used for the blocks to be used in the region of the flux line, that is, blocks that would resist the corrosive action of the glass batch, and the salts which formed on the surface of the glass, thereby resisting the attack better than would the ordinary type of block used for the bottoms of the sides or the bottom of the furnace itself. They also made a speciality of a type of block which was used for replacements; a block which could be used for the rapid reblocking of furnaces. In the manufacture of the tank blocks nearly all the makers used a mechanically-operated ram, worked by compressed air, for the purpose of ramming the clay into the mould. By the use of this mechanical ram, a block of very dense texture resulted. The majority of these block rams were very well constructed.

A good deal was heard in various factories of special methods which had been adopted in order to facilitate the drying of pots; but apparently this idea had not been carried to any very definite conclusion. So far as he could gather, the general impression was that where sufficient floor space could be given to the drying of the pots it was desirable to give them time to dry by natural methods rather than by any method of forced drying.

So far as the glass furnaces were concerned, Mr. Rees said he did not think we had much to learn from America in the matter of either design or construction. It was high time that the coal-fired furnace disappeared from our own country. In these days of high prices for fuel, he thought that every manufacturer in this country who used a coal-fired furnace ought seriously to consider the advisability of adopting gas firing, even though it meant a somewhat heavy capital expense in the erection of new furnaces, gas-producer plants, and so on. In the Pittsburgh district they had, of course, the immense advantage of natural gas. Quite a number of furnaces were still running throughout the year on natural gas with a calorific value of between 800 and 1,000 B.T.U. With a fuel like that one could do good work. But many of the factories in the Pittsburgh district were now having to install gas producers, seeing that the supply of natural gas was falling off very rapidly. In the winter, especially when there was a big demand for gas for domestic purposes, the supply was becoming strictly limited.

With regard to the gas producers themselves, the general tendency was to use a mechanical type. To those of the visitors who saw these batteries of mechanically-operated producers, there could be no question as to their superiority for gas-making purposes. They required less labour and gave a more uniform supply of gas. He was quite sure that one direction in which we in this country could move forward very markedly was in the installation of that type of gas-producer. The fuels used were, generally speaking, of much the same quality as those available in England. On the borders of the Pittsburgh district, and in certain other districts, the ash was perhaps a little lower than the British manufacturer was accustomed to, but, generally speaking, there was not much to choose between the two varieties of fuel. The great point to emphasise appeared to be that the Americans were making the best of their fuel by utilising efficient gas producers.

Concluding, Mr. Rees emphasised the great amount of care which the American silica brick manufacturers devoted both to the production of their bricks and the burning of them. Summing up the general impressions of his visit, he said he was rather surprised in one respect. He went to America expecting to see quite a good deal of what we in this country spoke of as American "hustle." American "hustle," as he had visioned it, did not exist; in fact, he quite believed from what he saw of American business life that the average English business man got through a good deal more work in a day than did the American business man. The latter, of course, talked a good deal, ran about a good deal, had a quick lunch, and so on, but one scarcely thought that he got through as much work as would have been expected from what one read and heard of the hustling methods of American business life. As for the cordiality of the reception which they had received everywhere, this was almost overpowering. In almost all cases it was easy to obtain permission to visit works and to witness the whole of the processes in operation.

Mr. G. P. Gass, said, speaking in regard to the machinery side of the industry, that an important lesson from the visit was that we should not be afraid of a capital expenditure on plant if it offered a reasonable chance of a fair return. He also thought that concentrated production of single articles would create a market here just as the same production had created markets in the U.S.A. He thought the lay-out of the plants particularly, right from the reception of raw material up to the glass furnace, was extraordinarily good in many of the works.

Mr. H. N. Clark desired to have the chance of voicing his appreciation and that of his wife in the privilege they enjoyed of going to the States with a party interested in the glass trade, and with such a man as Dr. Turner to look after them. He felt that if they had not taken advantage of it they would have missed the time of their lives.

He thought, after being taken to the Libbey Owens Glass Company in Charleston, W. Va., where window glass was being made, that in this country we had yet even to learn the ABC of glass engineering. Certainly, British glass manufacturers would have to instal engineering devices if they were to succeed.

Mr. Clark referred also to the courtesy he received everywhere, not only when travelling with the party, but also, as on his visits to the Dominion Glass Company's works, when he was alone.

Mr. Rees had already referred to the question of air in the pot-room. He, Mr. Clark, found in America that the windows of the pot-room were open during the making of pots. This struck him as being very strange, as he had been brought up in the idea that no air must get to the pots whilst being made.

Mr. W. B. Mitchell said that the trip interested him more especially from a bottle-making point of view. It was really marvellous to see the way in which the bottles were turned out by machinery. He thought in only one factory he went into were the bottles manufactured on what is called the American system of hand-work. To him, the factories, more especially the Owens bottle factories, were like huge generating stations rather than glass-working factories. It was really hard to find a man in the factories. He, too, would like to express his appreciation of the kindness and hospitality that were shown throughout the visit, both in the States and in Canada, and particularly the efforts of Dr. Tillotson in taking the party round and going to every possible trouble to make them comfortable.

In conclusion, he sincerely hoped that they would have an opportunity of doing something towards the entertainment of their American friends when they came over here.

Mr. H. A. Bateson said that as far as the manufacture of glass was concerned, it was the rate of production that impressed him. They saw everywhere a tremendous lot of milk bottles, tumblers, jellies, and beer bottles. We had often wondered whether we could not have the same production in this country as in America. Their factories, to his mind, were rather clean. The managers seemed to make a special point of putting notices up: "Let us see if we cannot make this factory the cleanest in America."

He would like to acknowledge most gratefully all the kindness shown in America. Coming home, also, they had quite a happy time, eleven of them together. He would like to say that the trip home had done him as much good as anything he had experienced for years; the kindness and help that were displayed one towards another made the voyage really an enjoyable time.

Mr. H. Gregg said, with regard to the methods in America, the first thing that impressed him was the large amount of cash required. The mechanical devices seemed to him to cost a small fortune. It was easy to spend a lot of money on them, and it was also easy to lose a lot. Before anyone could start with machines they must have really substantial capital.

Mr. W. C. Snowdon said it would appear from the speeches of his friends, and from observation in the works in America, that to be a successful glass manufacturer it was not so much necessary to know how to make glass, but one had to be a chemist, or an engineer, or a psychologist, because a chemist knew what he wanted, an engineer how to do what was wanted, and a psychologist knew how to persuade people to get it done, and how to sell the product.

Chemists had not been mentioned in the afternoon's discussion, but they were certainly used in America, and were successful. At Corning no fewer than twenty-five were employed, whilst at other places they had also introduced economical methods. These chemists, however, were not the "La-di-da" variety, but took off their coats and put on overalls, being quite often found down at the gas producers—where there were any.

The most lasting impression, however, was that of "soft crabs and green corn on the cob," mentioned by their friend Mr. Hodgson at Vineland. Much went with this impression, for it stirred up all the memories of the whole trip.

Mr. A. L. Foster said that, from the remarks already made, members of the audience might wonder if the party went out to learn or to have a good time, for the chief topic of the remarks seemed to be the hospitality of their American friends. They all appreciated that most fully.

He was not actually in the glass trade, although interested in glass production. As a layman, he learned a great deal out in America. He was afraid in this country we had too much of the John Bull in us. It was considered that what was good for England was good enough for the whole world, and he thought travel and interchange of ideas and methods were worth while. In regard to the glass industry, like Mr. Rees he was not impressed with the hustle of the Americans. The really hustling force in America was the automatic machinery, and, like Mr. Gass, he believed there was enough to encourage them to produce, if they would only go out and seek orders, and not confine themselves to the home trade. There was a lot of trade abroad they could have, but if they were not very careful someone else was going to take it. He referred particularly to Japan and parts of China. They were making great strides to get hold of the export trade that should be ours. Germany, he hoped, would be out of the market for foreign trade for many years. He did not know who would capture that trade, but America was doing a good deal. He believed that the country which lent itself to get that trade deserved it, and he hoped that country would be England.

He believed in free trade, not in a political sense, but because of the stimulus free trade brought with it. They could not consume all they manufactured in England, and if they were going to limit their own production to what they could use here, their goods would never be in great demand.

Viewed from this wide angle also, he would like to see in his lifetime Dr. Turner sending out from Sheffield University glass workers to all parts of the world.

Mr. R. L. Frink said some of the remarks made had brought to his mind rather forcibly the difference between the American and the English methods of manufacture. They had heard a great deal about science as applied to the glass industry, a great deal about engineering, but they very seldom found the word "psychology" as applied to the glass industry. He rather meant the industrial psychology to build up organisation and to produce, whether by machine or hand, that which would give profits to the manufacturer. It had come to his notice lately that machines had been brought over to England, had been erected, and attempts made to operate them. He had in mind one particular instance where the machine was in operation, and it was going through its operations in its usual manner, but the glass furnished to the machine, which meant everything indeed to the machine, was not furnished in a proper condition. Therefore, he had to say that the things seen in America ought to emphasise the fact that co-operation and organisation were really at the root of the success of the American glass industry.

Mr. C. W. Burtles (*communicated*): The great success of the American glass trade was due, first, to the supply of natural gas. This asset had helped greatly to allow the trade to grow. Secondly, it was due to the well-thought-out organisation, not only in the arrangement of factory buildings, but very largely also the shop or chair organisation in the factory. The latter, he understood, was largely due to and arranged by the workmen.

There was no limit to the amount of money a man might earn, except a minimum wage limit, but the difference between the maximum earned and the minimum was very great.

The consequence of this "no maximum" was that the men became organisers; and if they saw a way to increasing production by adding another member to the chair, this was done by arrangement with the employers. To such an extent was this organisation carried that he saw a chair with thirteen hands making tankard jugs. The arrangement of the lehrs in all factories was good, all running abreast along one side of the factory and emptying into a sorting room or warehouse.

Another matter which ought to be acted upon more generally in England than it is, was that all heating operations were scientifically controlled, so that the chart in the office showed the temperature of the furnace or lehr at any time during the twenty-four hours.

MR. SVEN FOGELBERG (*communicated*) thought his general impression of the American glass industry was "Wonderful machines, enormous works, and an unlimited supply of money." The products were good, sometimes very good, mass-products, but in very few places were real hand-made quality goods manufactured. The biggest difference between the glass-making in Europe and the new country seemed to be that the glass in Europe was an art production, but in America a *mass* production.

MR. A. S. GILES (*communicated*) said for one so new to the glass industry the whole visit and everything he saw were lessons. He thought the things, outside the remarkable hospitality of everyone he met, which struck him most were first the remarkable efficiency in small factories, which enabled very high production and good quality. The second remarkable thing which came to his notice was the great readiness with which one manufacturer would go to the assistance of another without any apparent desire eventually to profit unfairly by any knowledge of his rival's methods. The third point was one which he believed he emphasised while in the States, namely, that most Americans seemed to pride themselves on doing or trying to do things, in the industry, which had never been attempted before, in contrast to the somewhat slow and cautious waiting for someone else's initiative which seemed to be just dying out in this country.

He did not think, however, that the Americans realised our difficulties with regard to our natural resources of glass-making materials, as he had frequently a suspicion that American opinion of British glass was poor. They did not seem to have the same labour difficulties, as their workpeople were as progressive in the adoption of new methods as the proprietors of the factories—he almost said masters!

Another point was particularly brought home to him while paying a solo visit to a manufacturer in the Ohio Valley. The manufacturer told him that he had just had a busy day discussing his factory organisation problems with a competitor in the neighbourhood. Any assistance which he gained would be repaid when the competitor came the following week and saw how some of his own problems had been solved.

Mr. C. E. Towers (*communicated*) said that amongst his impressions he would mention, first, the large airy buildings, with plenty of floor room and generally much cleaner than ours; secondly, the almost universal use of tank furnaces; thirdly, the use of machinery either as an aid to or in place of hand labour.

As there was a fuller and much more accurate description in the October, 1919, Journal than he could ever hope to write of everything connected with the American glass industry, he would recommend the study of that account to anyone desiring information on American methods.

But perhaps the most lasting impression was the unfailing courtesy and kindness of everyone connected with the American industry and their readiness to allow one to inspect their works and everything in them—a lesson he was trying to learn.

Mr. Duncan Webb, jun. (*communicated*), said there were many salient points to make after visiting the American glass factories, and the one first to be mentioned was the unbounded hospitality all Americans accorded to members of their party.

They believed in the saying of Lord Avebury, the great British banker, that it was not enough to have a kindly feeling—they must show it.

The Americans had developed the physical study of glass and methods of mechanical handling, perhaps much more than the chemical, and appeared to have brought their studies to perfection in the Libbey Owens Sheet Glass Co. at Charleston, W. Va. Here the glass was drawn up in a straight sheet between rollers, and down the lehr at a rate of 40 inches per minute. This operation was conducted without the aid of a pushing block to flatten it. This factory, in his opinion, was the most up-to-date in the States.

Other factories visited used natural gas for melting their goods, giving greater heat and products of combustion less harmful to the glass. This natural gas, together with a protective tariff, in his opinion, gave America that supremacy in their own market which they now occupied.

Mr. J. Woolford (*communicated*) said he would deal with the workman's side in so far as it affected the flint glass industry. He was most impressed by the great amount of capital invested and the number of firms who had scientific help in the provision of good metal for the men to work. He was particularly struck by the absence of cords and stones, which, when present, made the workman's lot much harder and resulted in loss in wages, as almost all of the work was on the piece-rate system.

He was also impressed by the division of labour system which was in vogue. This in his opinion led to a greater production, and was much easier for the men, as it caused the work to be more equally divided, especially in mould blown work.

Further, he found that the American glass-maker had better facilities for production, such as leather gloves for handling hot irons and compressed air for cooling moulds, good hot holes for making the work, instead of working at the pot mouth, air for blowing iron mould work. All these little things were a help to production, and there was no doubt that America led the way in production with its great and costly machines, which could only be bought by big combines. He was convinced, however, that they were losing the fine art of glass-making, and, in conclusion, he felt that as a body the English glass-maker still led the way for best work.

XXXII.—*The Rate of Change of Glass Composition in a Tank Furnace following a Change in the Batch Composition.*

By John Currie, M.A.

It is known that when any radical change is made in the composition of a batch fed into a glass melting tank time must elapse before the new composition is thoroughly established in the working end of the tank. How slow this process is, however, is not generally realised. The experience of the author, who followed the progress of the change may be of interest to glass manufacturers.

The tank furnace in question had a dead weight capacity of 106 tons. During six working days in the week filling on takes place every two hours, the quantity added in each charge being made up of 30 cwt. of batch and 4 cwt. of cullet derived directly from the working end. The metal in this tank contained a fairly high percentage of lime, being used for bottles made on Forster machines. Semi-automatic O'Neill machines with Hartford-Fairmont feeder were installed in place of these, and it then became necessary to produce a glass of lower melting point and slower rate of setting. With this end in view the batch was altered so as to reduce the percentage of lime, at the same time increasing the percentage of alkali in the glass.

The batch originally in use with the Forster machines was as follows:—

Sand	1000 parts	Salt-cake...	133·3 parts
Limestone ...	400 ,,	Soda-ash...	133·3 ,,

The glass obtainable from this batch would have the following theoretical percentage composition:—

SiO_2………	67·64	CaO………	11·95
FeO ……	2·69	MgO ……	1·72
Al_2O_3 ……	4·16	Na_2O ……	11·84

The new batch was made up of—

Sand ………	1000 parts	Salt-cake…	133·3 parts
Limestone …	200 ,,	Soda-ash …	166·6 ,,

giving a glass the theoretical percentage composition of which would be:—

SiO_2………	71·28	CaO………	6·78
FeO ……	2·42	MgO ……	1·29
Al_2O_3 ……	3·96	Na_2O ……	14·27

This new batch was put into use on the 20th of November, 1919, and on the various dates mentioned thereafter a sample bottle was taken for analysis. The density of the glass was also determined, as shown in the table, and it is interesting to compare the gradual decrease in density of the glass with the varying composition.

The results are as follows:—

	Percentage Composition of the Glass.						Density at
Date.	SiO_2.	FeO.	Al_2O_3.	CaO.	MgO.	Na_2O.	15·5°.
Nov. 20th…	66·20	2·60	4·45	12·11	1·84	12·80	2·597
,, 25th…	66·74	2·61	3·95	11·43	1·83	13·44	2·588
,, 28th…	67·25	2·50	4·44	11·03	1·77	13·01	2·579
Dec. 3rd…	67.40	2·14	3·61	10·32	1·67	14·86	2·568
,, 5th…	68·28	2·13	3·90	10·30	1·70	13·69	2·567
,, 6th…	67·84	2·13	4·32	10·28	1·75	13·68	2·565
,, 11th…	68·89	2·02	3·78	10·00	1·47	13·84	2·563
,, 16th…	69·42	2·13	3·80	9·38	1·37	13·90	2·546
,, 18th…	69·29	2·37	4·17	9·18	1·34	13·65	2·545
,, 22nd…	69·55	2·37	3·70	9·37	1·37	13·64	2·543
,, 24th…	69·39	2·36	3·93	9·38	1·36	13·58	2·541
,, 29th…	70·42	2·24	3·38	9·02	1·47	13·47	2·541
Jan. 6th…	70·38	2·13	3·20	8·59	1·18	14·52	2·536
,, 12th…	71·00	2·12	2·58	8·09	1·05	15·16	2·521
,, 17th…	70·56	2·11	3·88	7·65	1·33	14·47	2·520
Feb. 2nd…	71·14	2·11	4·05	7·43	1·36	13·91	2·519
,, 16th…	71·27	2·21	4·50	7·42	1·42	13·18	2·518

It will be observed that after the lapse of almost three months the composition of the glass obtained was nearly, but not quite, identical with that calculated from the new batch, the percentage of lime being 7·42 as compared with 6·78 in the theoretical composition.

The progress of the change was not followed beyond this point, but the main fact established, in this particular case at least, is that a period of nearly three months was required to effect a radical change in the composition of the glass in the tank. The time occupied in bringing about the change will naturally depend upon the dead weight capacity of the tank and the rate at which it is worked, but both of these in this case are about the average for bottle glass tanks in this country.

In passing, it might be mentioned that in this run with Hartford-Fairmont feeder and O'Neill machines one of the chief difficulties encountered was due to the separation of crystalline calcium silicate in the metal at the fore-hearth. Frequent stoppages for various reasons, including repairs to the feeder, led to a lowering of the temperature at the working end of the tank. Subsequent re-heating in the fore-hearth by means of a blast of town's gas caused this devitrification to take place there, and, once formed, it was very difficult to eliminate, being at times quite as pronounced towards the end of this run when the lime content was low as it was at the beginning when the lime in the glass was 10 or 12 per cent. Nevertheless, with a glass sufficiently low in lime and correspondingly high in alkali, a combination of this kind for bottle-making should be eminently successful, provided that fluctuations in working temperature are at all times avoided.

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Discussion.

Dr. Travers said this was a very interesting paper, and recorded what to him was a very surprising thing. He thought that more information about the cullet, the tank depth, and general dimensions of the furnace were required in order to be able to understand this slowing-up of the change.

He hoped Mr. Currie would give all the data to enable full use to be made of the paper.

Mr. R. L. Frink would like to know if the changes in the batch were made at different periods. Unless it were known how rapidly the soda-ash was increased, it was very difficult to form an opinion as to whether the flow of the glass through the furnace would be retarded by the old metal.

Dr. Travers pointed out that, from the paper, the change of batch was made suddenly. Continuous change was made only in the cullet, not in the batch.

Mr. Rees said that so long a period as three months to complete the change in the batch at the working end was altogether extraordinary, even for a large tank. There must be some other factor at work in connection with cullet used or something which would explain the extraordinarily long time for the change. Particulars of the furnace might help to make the problem clear.

Mr. Guy Simpson said there was one other important question, namely, as to whether the tank was an open tank or one with a dog hole. Further, was the metal dark or light? The batch would take less time if the tank was open; in a bridge tank, it would take longer.

Mr. J. H. Davidson asked how the samples were gathered and from what depth was the metal likely to come.

Mr. A. E. Hill said there was another important point, namely, the stock of cullet held. If there were large stocks of cullet in hand of the old formula, and if these were used in rotation, it would naturally take longer than if the stocks were low, so that most of that used was taken from the working end.

Mr. Teisen would like to know whether the tank was supplied with a floating bridge or a syphon.

Dr. Turner (who communicated the paper on behalf of Mr Currie) said in some measure he felt a responsibility for this paper. He saw the data some months ago and believed they would form a good subject for discussion, and in this he had not been disappointed. There was a particular reason why he asked Mr. Currie to set out his experience; for, contrary to what other speakers had stated, he would like to say that Mr. Currie's experience was by no means extraordinary. When he first began to observe phenomena connected with some tank furnaces which could only be explained by the slow rate at which the metal composition changed, he himself had been astonished. But he had now met several similar cases. He was very pleased when he came across an instance of a chemist in charge of chemical operations who had actually taken the trouble to follow the course of the change in the special circumstances under which the tank was working.

In reply to some of the questions raised, he would say that the amount of batch filled on in two hours was 30 cwt. with 4 cwt. of cullet, so that less than one-eighth of the total weight filled on was cullet. Therefore the question of cullet was less important than had been inferred. The amount filled on in two hours would also give some idea as to the rate at which the glass was worked out of the tank. Mr. Frink asked if the change was made all at once, or if the amount of soda-ash was increased gradually. The change was made all at once. At a certain date the old batch was discontinued and the new batch as such in its anticipated final form was charged. Next, so far as the amount of cullet in stock was concerned, Mr. Currie would no doubt reply to that. In his paper Mr. Currie stated that the cullet used was that taken out of the working end of the furnace as the change proceeded. The samples were taken in just the ordinary mode of working, that is to say, by surface gathering. The samples were not simply dips of metal, but were taken in the form of a finished bottle, and the glass of this bottle was analysed.

There was just one other thing he (Dr. Turner) would like to direct attention to, namely, the somewhat variable rate at which the proportion of the soda present changed. Already, on the first trial, the percentage was one unit higher than calculated for the glass, and on December 3rd actually it distinctly exceeded what was anticipated as the final soda content. Somewhat similar variations took place with the samples taken on January 6th and 12th. He would like to know how the batch was mixed, whether by hand or by mechanical means. He had so often had to emphasise the necessity of thorough batch mixing that probably these somewhat irregular figures for the soda were also due to imperfect batch-mixing, and might provide an illustration of how the composition of the glass might be distinctly different from that anticipated if thorough mixing was not ensured.

MR. CURRIE (*communicated*) stated that he was gratified to know his short communication had aroused so much interest. He had much pleasure in supplying the following information in reply to questions raised.

The tank measured 25 feet 9 inches long and 15 feet 6 inches broad in the melting end. The working end was approximately semi-circular, the radius of curvature being about 7 feet 9 inches. The bridge separating the two compartments was a fixture, being 3 feet broad, and having a dog hole about midway across on the level of the tank bottom. The dog hole measured 16 inches high by 12 inches broad.

The metal, as evident by the percentage of iron oxide it contained, would be described as dark metal.

The temperature in the melting end varied from 1300° to 1400°, whilst at the working end it was about 1200°.

The stock of cullet in hand prior to making the change of batch was about 20 tons. This was all used up at first, after which the cullet was taken directly from the working end of the tank. He would add that the total charge of batch fed into the furnace between November 25th, 1919, and February 17th, 1920, was 1257 tons, and of cullet 179 tons. The amount used varied somewhat from week to week, usually ranging from about 95 to 110 tons.

As the Hartford-Fairmont feeder was in use, this implied that the metal was maintained at all times at a constant level, being 3 feet deep in the tank. If it had been possible to work the tank down by 5 or 6 inches at the end of each week, as happened in most tanks where hand-gathering was practised, then the change, no doubt, could have been effected in less time. Then, again, the fact that the new metal was of less density than the old prevented rapid diffusion from taking place. A converse change from low to high lime content would, no doubt, take place in much less time.

As regards the variable soda content, this happened because the salt-cake used was frequently very lumpy, and although the batch was mixed by machinery, the metal as it melted was not always of uniform composition.

It would also be observed that the alumina content was somewhat erratic. This was accounted for by the fact that the sand used varied considerably in composition.

XXXIII.—*The Influence of Silica on the Annealing Temperature of Glass.*

By S. English, M.Sc., F. W. Hodkin, B.Sc., Constance M. M. Muirhead, B.Sc., and W. E. S. Turner, D.Sc.

The question of the influence of silica on the annealing temperature of glass is a matter of very considerable interest; nevertheless, we possess no definite recorded information on the subject. If we may assume that each constituent oxide in a mixture of silicates in the form of a glass takes into that glass something approaching its own characteristics in the free state, then, since silica in any form has a high melting point and softening point, it might reasonably be conjectured that continuously increasing the amount of silica in a glass would raise the annealing temperature of the latter. Up to the present, data published are insufficient to make a reply one way or the other to this conjecture. In most glasses the constituent oxides vary, not only in type, but also in relative quantity, whilst the variation of annealing temperature with composition in a series of similar glasses does not apparently follow a very simple law. Accordingly, the effect of silica is not clear, and one is left to speculate whether or not the comparatively high annealing temperature needed for articles of glassware, such as miners' lamp glasses and glass cooking ware, is to be associated with the presence of large amounts of silica, or of some other constituent.

It is possible to get information on the subject in question in more ways than one. Thus, it is possible to compare a series of glasses containing three or more constituents in which the molecular proportion of the silica undergoes variation. It is also possible and simpler to study series of two component glasses in which we may regard the proportion of one constituent as fixed. This is the method which has been first attempted; others will be attempted, and what, in this paper, may be regarded only as the fringe of the subject will, it is hoped, be broadened.

The two-constituent glasses selected for examination were the sodium silicate glasses. These substances, well known in commerce as the basis of water glass, are useless for making articles of glassware, but do possess considerable interest in that it is possible by their study to deduce information on the respective effects of silica and sodium oxide in other glasses. Studies in this direction, indeed, have already been carried out by E. W. Tillotson * and C. J. Peddle.†

The Glasses and their Preparation.

The glasses studied varied in molecular composition in a definite manner, such that for each two molecules of sodium oxide the number of molecules of silica varied from 4 to 12. Table I states the approximate molecular composition and the batch composition, the latter being calculated on the basis of perfectly dry soda ash.

TABLE I.

Glass No.	Mols. of SiO_2 per 2 mols. of Na_2O.	Parts by weight of soda ash in batch per 1000 of sand.	Remarks on melting.
448	4	897	Readily melted and fined in five hours at 1300°. Very fluid at 1300°.
449	5	717	Melted at 1300°, less quickly fined than 448.
1	6	589	Melted and fined readily at 1350°; very fluid. 1300° too low for fining.
450*b*	7	513	Melted and fined at 1350° in twelve hours; 1325° too low for efficient fining.
479	8	448	1400° necessary for easy melting and fining. 1375° too low.
480	9	398	At 1350° remained seedy after sixteen hours' heating; at 1400° melted and fined in eleven hours.
481	10	359	Melted and plained in twelve hours at 1400°.
482	11	326	Very little melted during first two hours at temperature slightly exceeding 1400°. During the subsequent four hours melting was more rapid. Total melting and fining time, thirteen hours.
483	12	295	At 1430° batch only just fused after six hours. Only slight fining had occurred after eighteen hours. 1430° certainly too low.

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* E. W. Tillotson (*J. Amer. Cer. Soc.*, 1918, **1**, 80).

† C. J. Peddle, this vol., TRANS., p. 5.

Glasses 480, 481, and 1 were melted in 56 lb. pots, and the remainder in 28 lb. pots.

It may be remarked here that for practical purposes the series of glasses the physical properties (annealing temperature, thermal expansion, and density) of which were subsequently examined ended with glass No. 481.

As the glasses of the series became richer in silica, so, naturally, both melting and working them into tubing, rod, and discs became more difficult. This is evident from the data given below concerning their working temperatures.

The sodium silicate glass of the approximate composition $4SiO_2,2Na_2O$ was so fluid at 1100° that it could scarcely be gathered, whilst care and patience were needed to gather it at 1000°. At 800° it was still workable, the range 900—1000° being perhaps most favourable. This glass clings tenaciously to blowing irons.

A marked increase of viscosity occurred between glasses 448 and 449. The latter was very mobile at 1100°, and was still workable between 800° and 850°, but over the same range of temperature, namely, between 1100° and 950°, glass No. 449 was markedly more viscous than 448.

Glass 1 could be worked over a range from 1100° to 850°, but between this and the next glass, 450*b*, a noticeable increase of viscosity occurred, the latter not being worked easily at 900—950°. 1100° was approximately the best working temperature. When glass 450*b* was marvered, it became opalescent, and when drawn into tubing the latter on cooling had the appearance of fused silica (vitreosil). Clear rod and tubing could only be obtained by free working without marvering, this precaution being necessary, indeed, for all the subsequent glasses of the series.

At 1200°, glass 479 was too viscous for proper working. At 1300°, good tubing could be drawn without prior marvering.

Although viscous at 1300°, it was nevertheless possible to work glass 480 with satisfactory results. It was found that silica separation took place in the pot itself when the temperature fell to 1075°.

A further noteworthy increase of viscosity occurred between glasses 480 and 481 over the temperature 1300—1350°. The last glass which it was possible to melt, namely, 482, was difficult to work on account of rapid devitrification. The gathered glass on the pipe began to devitrify immediately air was blown into it, whilst opening the pot stopper and slight cooling due to the introduction of the gathering iron set up devitrification throughout the mass, although the temperature still remained at 1350°.

One further observation of interest was made during the working of the glasses, namely, that the rate of fall of temperature of the glass diminished as the percentage of silica increased.

Composition of the Glasses.

The glasses were analysed, and the compositions found are recorded in Table II.

TABLE II.

Glass No.	SiO_2.	Na_2O.	Fe_2O_3.	Al_2O_3.	CaO.	MgO.	Total.
448	66·91	32·74	0·05	0·07	0·04	—	99·81
449	70·38	28·84	0·07	0·37	0·04	—	99·70
1	74·05	25·34	0·14	0·24	0·21	trace	99·98
450*b*	76·27	23·51	0·08	0·12	0·22	—	100·20
479	79·13	20·34	0·07	0·29	0·04	—	99·87
480	81·34	17·96	0·06	0·17	0·04	—	99·57
481	82·83	16·98	0·08	0·28	0·02	—	100·19
482	84·01	15·64	0·08	—	0·04	—	99·77

The composition of glass No. 1 is taken from a previous paper.*

The Annealing Temperatures.

The upper annealing temperature of each glass was determined using a piece of rod with plane polished ends in the manner previously described. The results of the experiments are recorded in Table III below and in the diagram on p. 391.

TABLE III.

Glass No.	Annealing temperature.	Glass No.	Annealing temperature.
448	454°	451	515°
449	468	452	520
1	490	453	522
450*b*	506	—	—

It has already been shown that, as compared with the effect of sodium oxide, both lime and magnesia raise the annealing temperature of glass. There is provided in the results now given further evidence that sodium oxide makes annealing possible at a comparatively low temperature. This is readily seen by a comparison, for example, of glasses No. 1 ($6SiO_2,2Na_2O$) and No. 448 ($4SiO_2,2Na_2O$).

Conversely, the gradual addition of silica leads at first to a rapid rise of annealing temperature. This rapid rise, however, is not maintained, as will be seen most readily from the diagram.

It appears, therefore, that whilst in a simple glass of the sodium silicate type initial additions of silica have a marked influence, the annealing temperature of a glass with high silica content cannot be very high. It is conceivable, of course, that the annealing curve might change its direction again and turn sharply upwards at some point between 85 and 100 per cent. of silica, but, from the curves given, the annealing temperature of a glass containing nearly 100 per cent. of silica could not be expected to be very high.

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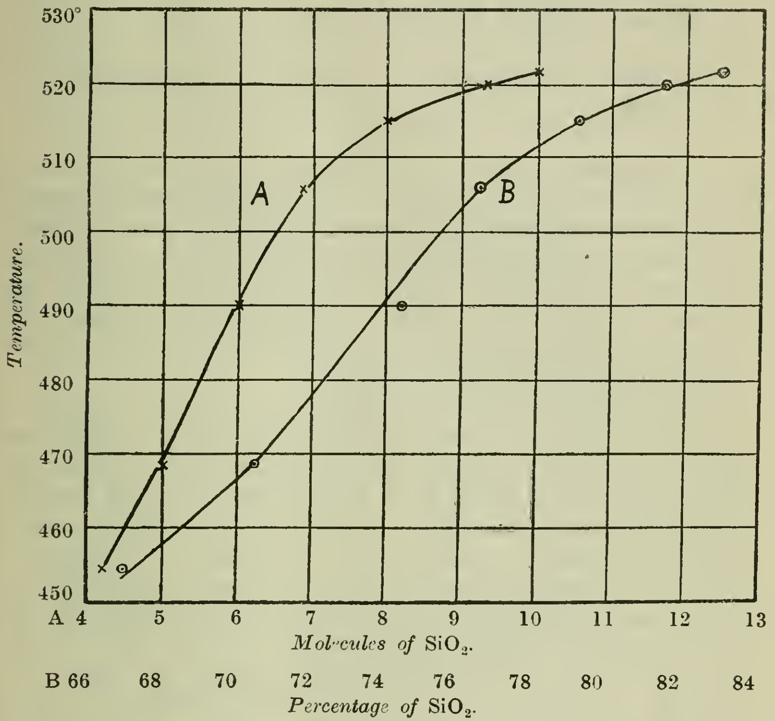
* This Journal, TRANS., 1919, 3, 227.



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XXXIV.—*The Effect of Added Felspar on the Shrinkage and Porosity of Aluminous Fireclays after being Fired at High Temperatures.*

By EDITH M. FIRTH, B.Sc., and W. E. S. TURNER, D.Sc.

(*Read at the Leeds Meeting, November 17th*, 1920.)

IN the detailed account of the properties of a large number of British fireclays given in an earlier paper,* one section of distinct interest concerned the effect of fluxes on the shrinkage and porosity. Of special interest were the clays containing a high or moderately high content of alumina. These clays were the ones which more than any others showed a regular change in the shrinkage, whilst with two notable exceptions the highly aluminous clays were shown to possess the widest range of porosity.

It was found possible approximately to correlate the percentage of the total fluxes with the shrinkage and porosity. Thus it was found that, for the most part, the clays with a high shrinkage contained more than 2 per cent. of total fluxes, and much the same conclusion was to be drawn in connection with the porosity, namely, that those containing a rather high percentage of total fluxes showed a big range of porosity, whilst in those comparatively free from fluxes this property underwent no great change. It was further suggested that a clay with only a small porosity range, especially if the actual porosity were high, might have that range increased if the amount of the total fluxes was increased, and that this increase might be accomplished by the addition of felspar.

The two clays which, although of high alumina content, had only a short porosity range were the Ayrshire Bauxitic Clay and Kilwinning Aluminous Shale. These clays, as already remarked, provided the exceptions to the fairly general rule that an aluminous clay usually had a wide porosity range. It seemed, therefore, of very considerable interest to ascertain if, and to what extent, the addition of fluxes in the form of felspar might be successful in increasing the porosity range of these clays, and it is in connection with these two types that the experiments outlined below were carried out. If it could be proved that these highly aluminous clays only needed additional fluxes to increase their porosity range by a considerable amount, then further evidence was forthcoming that the aluminous clays could with suitable treatment be given a porosity after being fired which would vary over a very considerable range, thus indicating that they might be adapted to a fairly wide set of conditions.

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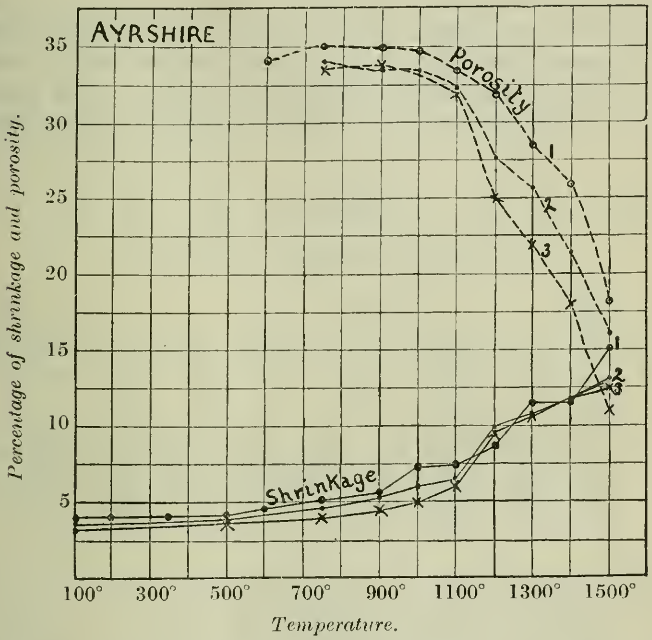
* Edith M. Firth, F. W. Hodkin, and W. E. S. Turner, this vol., TRANS., 162.

It may be remarked here that when these experiments were undertaken the paper by S. R. Scholes* dealing with a lining for glass pots had not come to our knowledge, and although one of us was aware that Dr. Scholes had developed a successful lining for pots, the method of obtaining it by the use of felspar was unknown to us. The paper in question does not give in detail numerical values of the effect of felspar on the shrinkage and porosity of fired clays, and our work therefore provides definite experimental data which not only prove the conjectures made in the previous paper, but also furnish evidence in support of the idea underlying Scholes's process.

Fig. 1.



EXPERIMENTAL.

For the purpose of experiment, the two clays selected were the Ayrshire Bauxitic Clay and the Kilwinning Aluminous Shale. To each of these clays in turn amounts of felspar were added so as to increase the total amount of flux by 1 per cent. and 2 per cent. respectively; that is to say, three clays were compared in each case, namely, the original Ayrshire or Kilwinning Clay as the case might be, and mixtures of each clay with felspar added, so as to bring up the total fluxes as indicated. In Table I below, containing the percentage compositions, the original clay in each case is designated 1, and the mixtures with 1 and 2 per cent. of additional flux as 2 and 3 respectively. The actual amount of felspar added to Ayrshire 2 was 9·0 per cent., and to Ayrshire 3, 18·1 per cent. In the case of Kilwinning 2, 9·7 per cent. of felspar, and Kilwinning 3, 19·4 per cent.

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* S. R. Scholes, *Trans. Amer. Cer. Soc.*, 1920, 3, 498.

Although from the previously known composition of the fireclays and the known composition of the felspars it was possible to calculate the composition of the mixtures, it was decided that in order to leave no doubt each mixture should be analysed. The mixture employed for analysis was that which had passed through a 30-mesh sieve.

TABLE I.

Percentage Composition of Materials.

Material.	Loss on ignition.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	K_2O.	Na_2O.	Total fluxes.
Felspar	0·40	72·78	15·44	0·42	nil	0·92	trace	6·12	4·62	—
Ayrshire.										
1	14·14	36·40	45·09	1·00	2·86	trace	trace	0·29	0·30	0·59
2 (calc.)	12·88	39·67	42·40	0·95	2·59	0·08	trace	0·81	0·69	1·58
expt.	12·82	39·60	42·38	0·91	2·76	0·10	trace	0·89	0·61	1·60
3 (calc.)	11·65	42·97	39·74	0·90	2·34	0·17	trace	1·35	1·08	2·60
expt.	11·55	42·82	39·74	0·85	2·58	0·17	trace	1·37	1·08	2·62
Kilwinning.										
1	13·80	42·74	33·90	4·87	3·75	0·23	0·36	0·62	0·15	1·36
2 (calc.)	12·50	45·74	32·11	4·44	3·38	0·30	0·32	1·15	0·59	2·36
expt.	12·25	48·76	29·40	4·02	3·48	0·30	0·30	1·18	0·57	2·35
3 (calc.)	11·19	48·66	30·32	4·00	3·02	0·36	0·29	1·69	1·02	3·36
expt.	10·98	51·36	27·84	3·62	3·12	0·34	0·30	1·72	1·01	3·37

It will be noted that in the case of the mixtures of the Ayrshire Clay the calculated and actual compositions agree closely. In the case of the Kilwinning Clay, there is distinct difference between the calculated and experimentally determined value for silica and alumina. It has been noted, however, that the value calculated is based on an analysis of the clay as a whole, and not on the sieved clay as used for making slabs.

The Shrinkages and Porosities.

The mixtures were made up into slabs in the manner described in the previous paper.*

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* *Loc. cit.*

The shrinkages were also determined as before, beginning at a temperature of 110°. In the present experiments it was also possible to include investigation at a temperature of 1500°. In the case of porosities, the initial experiments were made after the slabs were fired at 750°.

Tables II and III set out the shrinkages and porosities respectively.

TABLE II.

The Shrinkages.

	110°.	500°.	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.	1500°.
Ayrshire.										
1	3·92	4·07	5·16	5·55	7·28	7·39	8·75	11·54	11·57	15·11
2	3·56	3·92	4·59	5·29	6·13	6·55	9·91	10·71	11·64	11·85
3	3·19	3·45	3·97	4·52	4·97	5·92	9·57	10·66	11·79	11·84
Kilwinning Aluminous Shale.										
1	3·31	3·25	3·78	4·26	4·76	5·18	6·73	7·05	7·17	7·98
2	3·05	3·30	3·46	3·78	3·97	5·00	6·60	7·22	7·78	9·78
3	2·71	2·86	3·02	3·56	3·67	4·55	6·58	7·77	8·55	9·41

TABLE III.

The Porosities.

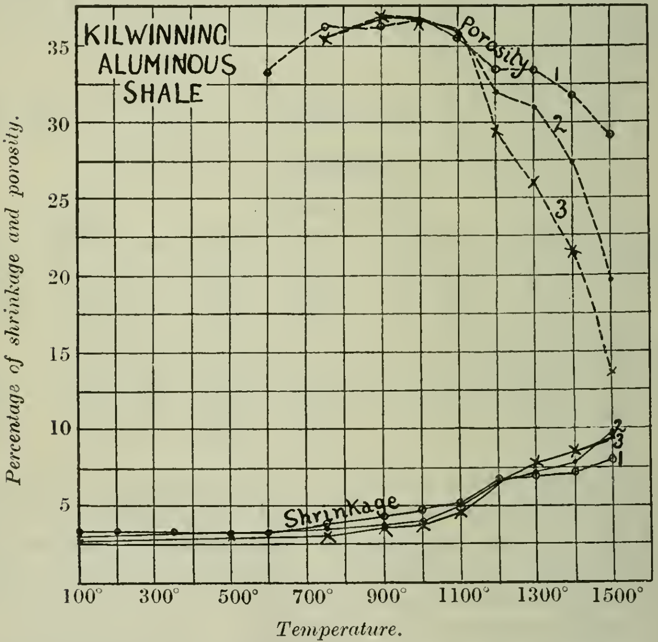
	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.	1500°.
Ayrshire.								
1	35·1	34·9	34·7	33·4	31·9	28·5	25·8	18·3
2	34·1	33·6	33·4	32·4	27·6	25·7	21·5	16·1
3	33·6	33·8	33·2	31·8	25·0	21·9	18·1	11·2
Kilwinning Aluminous Shale.								
1	36·6	36·6	36·7	35·6	33·6	33·5	31·8	29·2
2	35·4	36·9	36·8	35·9	32·0	31·0	27·4	19·7
3	35·4	36·8	36·7	36·0	29·6	26·0	21·6	13·7

It will be seen in both cases that up to a temperature of between 1000° and 1100° the shrinkage of the mixtures is distinctly less than that of the original clay, and the mixture containing the most felspar has in each case the smaller shrinkage. Up to this temperature, probably the felspar performs the function rather of grog, and does not begin to have any fluxing action. At a temperature of 1100°, however, in the case of the Ayrshire clay, the shrinkage of the mixture begins distinctly to approach that of the original clay, and at 1200° actually exceeds it. This increase in shrinkage over that of the original clay is not maintained, however, since between 1300° and 1500° the original clay undergoes considerable shrinkage, particularly between 1400° and 1500°, whereas the increase of shrinkage for the mixtures takes place more slowly. In the case of the Kilwinning clay the shrinkages of the original and the mixtures are not far removed from one another at 1200°, whilst thereafter the values for the mixtures exceed those for the original clay.

On the whole, as seen from the accompanying diagrams, the addition of felspar reduces the shrinkage up to a temperature somewhere in the neighbourhood of 1100°, and after that temperature it may increase the shrinkage somewhat. What is fairly clear, however, from the two diagrams is that the change in the shrinkage is more uniform when felspar is added, that is, when the total fluxes are increased.

In regard to the porosities, there is no very great difference up to a temperature of 1000° in the case of the Ayrshire clay and 1100° in the case of the Kilwinning shale between that of the original clay and those of the mixtures. With Ayrshire clay at 1100° the addition of 2 per cent. of total fluxes has already become slightly effective in reducing the porosity, whilst at 1200° the effect is very marked. With Kilwinning shale a marked diminution of porosity, which can be assigned to the presence of the increased amount of felspar, takes place somewhere between 1100° and 1200°.

Fig. 2.



It is very interesting to note that the effect of temperature alone between 1400° and 1500° brings about a very big reduction of the porosity of the Ayrshire clay. The Kilwinning clay is not influenced in anything like the same manner.

Determinations of apparent specific gravity and of the specific gravity of the clay material do not provide data of the same value as the shrinkages and porosities. For the sake of completeness, however, the specific gravities were determined, and are tabulated in Tables IV and V.

Table IV.

Apparent Specific Gravity.

	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.	1500°.
Ayrshire.								
1	1·72	1·74	1·84	1·83	1·91	2·06	2·14	2·34
2	1·71	1·74	1·78	1·80	2·02	2·07	2·18	2·25
3	1·71	1·73	1·75	1·81	2·02	2·12	2·20	2·25
Kilwinning.								
1	1·67	1·73	1·72	1·74	1·80	1·81	1·86	1·90
2	1·66	1·68	1·69	1·70	1·84	1·86	1·93	2·06
3	1·66	1·68	1·69	1·70	1·86	1·96	2·05	2·08

Table V.

Specific Gravity of the Clay Material.

	750°.	900°.	1000°.	1100°.	1200°.	1300°.	1400°.	1500°.
Ayrshire.								
1	2·64	2·67	2·82	2·75	2·79	2·88	2·88	2·86
2	2·59	2·64	2·68	2·67	2·73	2·81	2·81	2·67
3	2·57	2·62	2·65	2·66	2·70	2·72	2·69	2·53
Kilwinning.								
1	2·63	2·74	2·72	2·70	2·71	2·72	2·72	2·69
2	2·57	2·69	2·69	2·68	2·68	2·71	2·65	2·57
3	2·56	2·68	2·68	2·68	2·66	2·66	2·61	2·41

It will be seen from the data that with both the clays the apparent specific gravity increases steadily with the rise of temperature, and that increasing the felspar content raises the apparent specific gravity.

In the case of the specific gravity of the clay material, there is no continuous increase in value, whilst the actual specific gravity diminishes as the amount of fluxes is increased.

General Conclusions.

Two aluminous clays of very high porosity at low temperatures (about 900°) and of short porosity range have been tested to ascertain the effect on them of the addition of felspar as a flux.

The addition of felspar as a flux diminishes the shrinkage up to a temperature of about 1000° to 1100°, and in general apparently makes the change in shrinkage more uniform.

The effect of increasing the amount of felspar is to bring about a considerable reduction of porosity at temperatures exceeding 1100—1200°.

The results now obtained give confirmation to the view previously expressed, namely, that aluminous clays in the presence of suitably adjusted amounts of flux can be made to undergo a wide change of porosity when fired at a high temperature. Provided, therefore, the amount of flux is not excessive, the presence of fluxes in aluminous clays need not necessarily be a disadvantage. What the actual limit of the fluxes should be can be determined only in conjunction with the study of other properties than those now determined, such, for example, as the refractoriness and resistance to corrosion.

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Discussion.

Mr. P. Marson (*communicated*).—The investigation on added felspar to fireclay and the advancement of the study to 1500° has developed many points of interest. The results amply justify the extension made to the higher temperature range.

The delayed shrinkage of the felspar bodies compared with the original clay during the biscuit stage certainly confirms the point brought forward by the authors, namely, that felspar acts as a grog or shortening material during the preliminary stages, and it is only at 1200° that its sintering influence becomes effective. No doubt it will be found later that those bodies with felspar will give greater resistance to corrosion. This would then confirm the observations Dr. Travers made in his statement that, to increase the resistance to corrosion, pots should not be filled with batch until the clay has matured under heat sufficiently to approach the sintering stage. Provided, also, the tensile strength of these highly aluminous refractory clays is not adversely affected, it is quite feasible that such clays would be improved by small additions of felspar in order to lessen the permeability to molten glass. Even if at the higher furnace temperatures it were found that the margin for load carrying was exceeded, it should be possible to use the felspar admixture for the pot bottoms alone, and thus lessen the tendency of that portion of the pot to be attacked by the molten glass more than the sides.

In practice one was not limited to felspar alone as the vitrifying agent, and in his view Cornwall stone would be a better material than felspar for the purpose, as the alkalis were therein more diffused and the intimacy of the action spread. There was also the possibility that admixture with the less refractory fine-grained slip clays, which contained more than a normal amount of alkali, might give the desired effect of a dense, sintered body of sufficient refractoriness.

He had reason to expect a further advantage from the felspar addition to these aluminous clays in the light of Mr. G. V. Wilson's researches on *sillimanite* formation in pot clays. The presence of potash might increase the formation or tendency for this essential mineral to form in pot bodies, and consequently corrosion should be delayed. He would like to utter a warning note to practical pot-makers against indiscriminately mixing felspar with any pot-clay mixture, as the admixture was only justified where the clay used was highly refractory and where the porosity value was shown to be higher than consistent with resistance to corrosion by the molten glass. He doubted if many of the present pot-clay mixtures used would stand a 9 per cent. felspar addition without showing sagging or bulging in use. Still, he could conceive many instances where a moderate addition of felspar to that portion of clay used for the bottoms alone would be an improvement in lessening the solubility of that portion where the furnace heat was unable to get free access. The real interest of the paper was in showing how the higher refractory clays could be modified after being fired to suit certain requirements.

He thought, also, that the results obtained could be directly applied to the improvement of tank blocks, where the decreased porosity as the result of the added felspar would increase the working life of tank furnaces by increasing the resistance of the blocks to corrosion.

He would like to ask the authors in what way the felspar was added to the bodies, if in the form of water-ground slip or as the dry felspar just ground along with the 30-mesh clay, and if any soaking or re-tempering of the mixtures preceded the work. Naturally, with so active a flux as felspar, the most intimate mixture would be desirable to give steadiness in the working life of the pot.

Further, he would like to ask the authors if they made any definite estimation of carbon during the analysis of these two particular clays, and if the presence of carbon could be correlated with any of the effects they had observed during their study of these two clays. During some practical observations on the behaviour of pots made from the Ayrshire clay, and also from the Ruabon and Coalbrookdale clays, he noticed a more than normal tendency to black coring and blue-stoning, even with careful firing. This he attributed to the presence of carbon.

Mr. W. J. Rees (*communicated*) said that the results detailed by the authors were in agreement with laboratory observations he himself had made on mixtures of felspar and china-clay and on aluminous ball-clays containing high proportions of fluxing impurities. The paper really emphasised the frequent necessity for making some sacrifice in ultimate refractoriness of a clay in order to secure some such property as low porosity over a given range of temperature. Equilibrium might, however, not be attained until after heating for some considerable time over the given range of temperature, owing to the gradual formation of increasing quantities of "melt" by interaction of the fluxes and the constituents of the clay. It was noteworthy that, whilst considerable quantities of such a flux as felspar or mica might be added to a pure (non-siliceous) clay, without very seriously affecting its normal refractoriness, because of the high viscosity of the melt produced (Simonis,* for instance, showed that the addition of 30 per cent. of orthoclase to Zettlitz kaolin only lowered its refractoriness from cone 35 to cone 31), the effect on the load-carrying capacity of the clay was much more marked, the reduction in viscosity being sufficient to prevent the clay carrying a load, although insufficient to bring about deformation under its own weight.

It was of some practical importance to differentiate between open and enclosed pore-spaces, particularly when vitrification had commenced. Very frequently during vitrification some of the finer channels were closed, and a portion of the pore-space was thus cut off. Presumably, the figures given in the paper referred to total porosity. One of the difficulties in the use of bauxite and bauxitic shales had been the great contraction at temperatures above 1400° and the prolonged high temperature treatment necessary in order to obtain products which on subsequent use showed no further pronounced contraction.

Dr. Turner (*communicated reply*) said that in the preparation of the mixtures of clay and felspar the latter was added in the dry state, thoroughly incorporated in the clay, made up with water, and allowed to stand overnight prior to slab-making. Mr. Marson's suggestion in regard to the determination of carbon was one well worth consideration in any further examination of the clays. The determination had not been carried out in the present investigation. Only in one instance, namely, that of the Coalbrookdale clay, had any black coring been observed as the result of firing. It must be observed, however, that electrical heating in a non-reducing atmosphere, such as was carried out in the tests, would scarcely tend to the production of black cores to the extent observed when fireclays were heated in a gas-fired furnace. In regard to the porosities, these were the total values and did not differentiate between open and enclosed pores.

He would like to express his thanks both to Mr. Marson and to Mr. Rees for their valuable comments.

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* *Sprechsaal*, 1907, **40**, 29; 1908, **41**, 42.

ABSTRACTS AND REVIEWS

NOTE.

1. The abstracts of British Patents are taken from the official abstracts in "Illustrated Official Journal (Patents)."
2. The fact that an abstract is given of a U.S.A. Patent Specification does not necessarily imply that there is no corresponding British Patent Specification.

I.—Glass-making Materials.

1. Potassium Salts from Blast Furnace Dust. Stafford Coal & Iron Co., Stoke-on-Trent, and J. R. Richmond. (Brit.

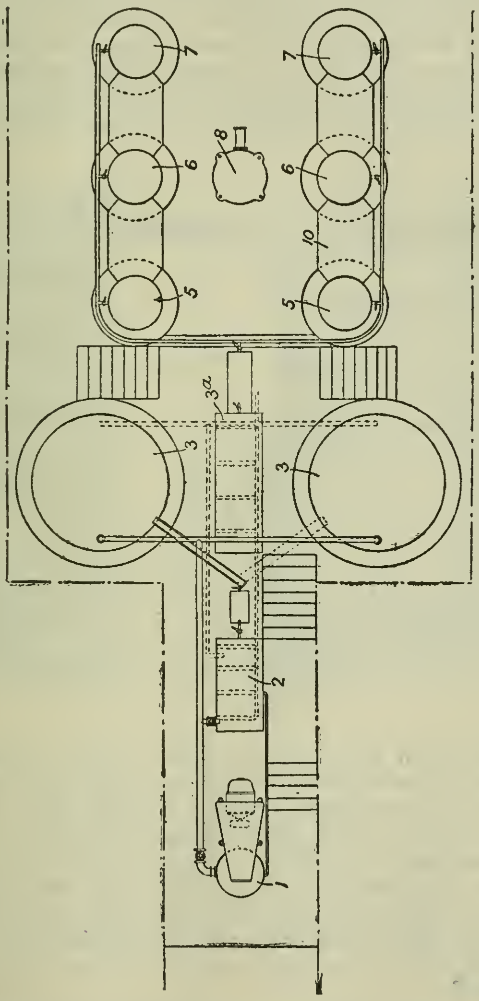

Fig. 1.

Pat. No. **117991.**) (September 8th, 1917, No. 12887).—Blast furnace flue dust is dissolved in water and treated with air to render the iron compounds insoluble. Lime or the like is then added to precipitate magnesia, and the solution is then evaporated to dryness and calcined, the residue being finally redissolved and evaporated to obtain crystals. Ammonium chloride may be obtained by giving the dust a preliminary heating, or ammonia may be recovered when the lime is added. H. G. C.

2. Sifting Machinery. A. C. Harrison, Stoke-on-Trent (Brit. Pat. No. **118800.**) (March 5th, 1918, No. 3823).—A machine for sifting potters' slip, powdered substances, etc., consists of a frame, *a*, carrying detachable lawn frames or sieves, *b*, *c*, *d*, placed one above the other, and a collecting-box, *e*, below the lowermost sieve, rocked on a shaft, 2, arranged longitudinally and in the centre of the machine by means of a link, 7, and a crank, etc. Springs, 9, mounted on a fixed structure, engage with the frame and tend to keep it in the vertical position. The detachable sieve frames are fitted with inclined sieves provided with inclined partitions, *t*, to convey the material passing through one sieve to the upper end of the next sieve, and are open at their lower ends. The sieve frames are clamped up in the frame, *a*, by clamping screws, *m*, and the tension of the sieves may be regulated by eccentric rollers bearing across their lower surfaces. Buffers, 8, may be provided below each corner of the rocking frame. In a modification, the rocking frame is suspended from an overhead shaft carried by a beam. H. G. C.

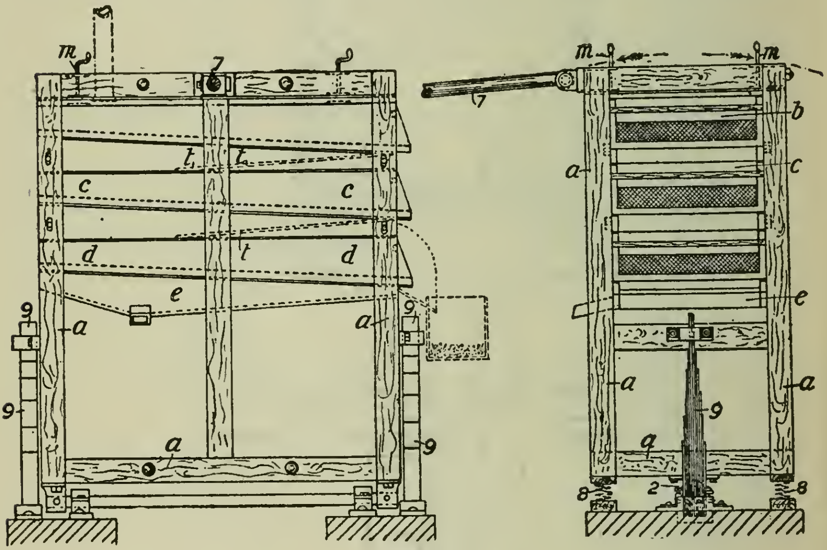

Fig. 2.

3. A Comparison of Dolomites. A. Rothrock and J. B. Shumaker (*Chem. News*, 1920, **120**, 29).—The compositions of a

No.	Source.	Physical characteristics, etc.	Spec. Gravity.	Composition.					
				SiO_2.	Fe_2O_3.	Al_2O_3.	$CaCO_3$.	$MgCO_3$.	Total.
1	Ossining, N.Y.	White ; crystalline ; very compact.	2·93	10·61	0·20	Trace	51·97	37·40	100·18
2	Cumberland, England.	Dark grey ; massive.	2·88	0·56	16·05	0·87	57·59	24·98	100·05
3	Cerro Gordo, California.	Light coloured ; massive ; non-crystalline.	2·57	0·06	0·09	—	87·88	11·85	99·88
4	Frankenstein, Germany.	Grey ; compact ; massive ; hard ; conchoidal fracture ; neither granular nor crystalline.	2·9	0·13	3·71	0·73	27·04	67·91	99·52
5	Keeler, California.	White ; very hard ; compact ; crystalline ; resembles marble.	2·7	32·57	0·06	—	66·08	1·15	99·86
6	Binnenthal, Switzerland.	Greyish-white ; contains transparent crystals ; resembles marble ; crumbles easily.	2·85	10·84	0·48	—	49·00	40·23	100·55
7	Gerolstein, Germany.	Hard ; compact ; massive.	2·82	1·23	0·80	0·22	52·93	44·33	99·51
8	Costa da Val, Tyrol.	Pearly lustre ; coarse particles ; light colour with yellow streaks ; closely approximates to $2CaCO_3 \cdot MgCO_3 \cdot FeCO_3$.	3·01	0·12	2·36	—	49·59	24·50	100·01*
9	New Almadin, California.	Greyish-white ; hard ; very compact ; long, coarse crystals ; one surface coated with brown deposit.	2·8	0·4	8·57	—	53·28	45·18	100·11?
10	Raible, California.	Light grey ; fine, granular crystals ; somewhat porous.	2·7	0·23	trace	0·28	54·64	45·18	100·33
11	Brewster's, N.Y.	Grey ; large, rhombic crystals.	2·9	0·33	2·44	—	59·98	36·83	99·58
12	Missouri.	Outer layer : light pink crystals.	—	0·23	1·18	0·63	56·63	41·37	100·04
		Inner layer : dark grey crystals.	—	3·96	0·89	1·16	57·18	36·83	100·02
13	"The Dolomites," Austrian Tyrol.	Grey.	2·73	0·48	0·56	0·57	94·21	4·15	99·97
	Brenner, Brenner Pass.	—	—	0·35	0·50		96·25	2·98	100·08

* Includes $FeCO_3$, 23·44.

number of dolomites, or supposed dolomites, were given as follows, showing wide variations from the typical dolomite $CaCO_3,MgCO_3$, which contains 54·35 per cent. of $CaCO_3$ and 45·65 per cent. of $MgCO_3$. F. W. H.

4. Potassium Salts from Glauconite. F. TSCHIRNER, Newark, New Jersey, U.S.A. (Brit. Pat. No. **117870**.) (November 2nd, 1917, No. 16013).—A process for obtaining potassium chloride from glauconite. H. G. C.

5. Potassium Chloride Preparation. E. A. ASHCROFT, London. (Brit. Pat. No. **119492**.) (August 28th, 1917, No. 12363). —A process for obtaining potassium chloride from potash-bearing minerals, such as felspar, mica, alunite, or leucite, or from cement-kiln dust, blast-furnace dust, wood or plant ashes, beet-sugar residues, etc., by treating the substances with chlorine gas while suspended in a fused bath of sodium or potassium chloride, or a mixture. H. G. C.

II.—Glass: Manufacture and Properties.

6. Glass and some of its Problems. H. JACKSON (*J. Roy. Soc. Arts*, 1920, **68**, 134).—Dealing with the relative plasticity of various glasses, it was pointed out that the satisfactory sealing of wires into glass did not depend solely on the coefficients of expansion of the materials concerned. Certain glasses gave successful joints with platinum and copper wires, but always cracked with iron wire, although the coefficient of expansion of copper was double that of platinum, and that of iron about midway between the two. Examination showed that in the case of the softer metals, like platinum and copper, the glass, on setting, could deform the wires, and so tend to prevent excessive strain being left in the glass. In the case of harder metals, like iron and tungsten, it was necessary to have a glass which showed considerable plasticity over a sufficient range of temperature to permit of the glass flowing and following the contraction of the wire when the joint cooled.

Plasticity was also concerned in the durability of glass vessels when subjected to sudden changes of temperature. The coefficient of expansion was again an important factor, but if the strain set up in the glass, due to change of temperature, could be rapidly released, the tendency to crack would be diminished. It was possible to make a glass having a higher coefficient of expansion which would not crack so easily as one having a lower coefficient of expansion, owing to the greater plasticity of the glass with the higher coefficient of expansion.

The structure of glass and the phenomena of crystallisation were illustrated by reference to the behaviour of arsenic trioxide, sulphur, zinc silicate, lime–soda–silicate glass, and a number of borates. There was a certain temperature at which crystallisation proceeded readily, whilst for small ranges above and below that temperature no crystallisation occurred. With alteration of temperature there was a corresponding change of viscosity, with the consequent modification of the freedom with which the particles of the substance could move among themselves. When the viscosity was too great, rearrangement of particles to form crystals was prevented. Gases, as foreign matter in the materials, aided crystallisation, as illustrated by the behaviour of water and phenyl salicylate. Removal of the gas made it possible to cool the material many degrees below its melting point before crystallisation took place. Simple silicates and borates gave off water vapour on alternate melting and solidification, and with the progressive removal of the water vapour the vitreous state persisted more and more. Direct introduction of water subsequently, readily promoted crystallisation.

Etching with hydrofluoric acid, and also tearing the surface of glass by means of a glue film, caused markings on the glass, which had a network appearance, but examination under the microscope gave no evidence of crystalline structure, and the phenomenon was more probably due to surface tension. A study of the phosphorescence of vitreous compounds, including glasses, gave rise to the conclusion that a truly vitreous body exhibited no phosphorescence in ultra-violet light or X-rays, or under cathodic discharge. Nearly every glass showed some phosphorescence, which suggested that there was something of a crystalline nature in the glass. Boric anhydride, which had a marked effect in preventing crystallisation in glass, that is, in preserving the vitreous state, was a fatal ingredient to add to a uranium glass if strong fluorescence in ultra-violet light was desired. The question whether glass was crystalline or not had an important bearing on the production of glass for lampworking purposes. The segregation of less fusible vitreous bodies, giving a kind of crinkled skin to the glass, the separation of amorphous silicates, the formation of minute bubbles, giving a grey appearance to the glass, as well as true crystallisation, were all frequently referred to as devitrification. Concerning the last-mentioned trouble, apart from temperature, which was the most important factor, there were two problems to be considered. It was pointed out that a soda-lime silicate could be made which could scarcely be worked at all in the flame, owing to rapid devitrification, yet could be worked if heated by radiation in a muffle furnace. The problems arising were, first, whether working in the flame caused the surface of the glass to be raised to a very high temperature, and a thin layer of glass accordingly reached the requisite state of fluidity for crystallisation, or, secondly, whether the hot gases of the flame had a chemical action on the glass. Experiments directed towards the solution of these problems appeared to justify the conclusion that water and carbon dioxide did act chemically, and such action played an important part in the initial stages of devitrification. Other than boric anhydride, previously mentioned, the oxides of aluminium, titanium, zirconium, tin, thorium, arsenic, and antimony tended to prevent devitrification. The disadvantages attending the use of some of these oxides were also mentioned. Soda glasses were more liable to devitrify in the flame than potash glasses or glasses containing a fair proportion of potash with soda.

The production of various types of opal glass was briefly discussed, and the distinction between opalescence and devitrification indicated. Examination under the microscope showed that in the usual opals the opalescence was due to the scattering of light by numerous small globules evenly diffused throughout the glass with no evidence of crystallisation.

Dealing with coloured glasses, the author discussed the production and properties of glasses containing gold, copper, and selenium as representative of those glasses in which the colouring was diffused in very minute particles throughout the glass, and which could be compared with colloidal solutions. Gold gave colours varying from red through the purples to blue; copper, in the metallic state, gave a red normally, but would also give variations similar to gold, even to a definite blue, by transmitted light; selenium glasses were generally red, but various states of division would give other colours. Whilst accepting the chemical and physical evidence that, when they did give colour, the three substances mentioned were in the elementary state, the author considered that it did not necessarily preclude the possibility that there might be something akin to chemical combination in the case of the chilled and colourless glasses.

Interesting experiments were described which gave some light on the development of the pink or violet colour in window glass. Glasses containing small amounts of manganese dioxide and as little iron as possible were made, and these were practically colourless to the eye. On exposure to radium, some of the glasses were coloured, but others remained colourless. The former were made under conditions which caused as little deoxidation of the manganese as possible, whilst the latter were made under conditions which were arranged for complete reduction of the manganese. Rods drawn from one of the former glasses, which cooled practically colourless, "struck" a violet colour on re-heating. After noting the connection between this effect and the question of the chemical condition of colouring agents in glass, the author pointed out that it was possible that the colours in old window glasses were not due to manganese dioxide itself, but that the manganese might have rendered the alkali compounds in the glass more sensitive to light of short wave-lengths.

As examples of those glasses in which the colouring agents were in a state resembling solution, and which might be compared with aqueous solutions of coloured salts, nickel and cobalt glasses were described, and also the effect of different alkalis and the effect of varying proportions of an alkali. Using equivalent proportions of the alkalis and the same amount of nickel, a potash glass gave a deep violet, a soda glass a brown with a faint violet tinge, and a lithia glass a yellowish-brown of less colour intensity than in the soda glass. Similarly, cobalt gave blue colours with potassium and sodium, and a bluish-violet, less coloured, with lithium.

The effect of alkalies on borate glasses containing nickel and cobalt was dealt with in similar fashion, and also the effect on glasses containing copper oxide. The changes of colour observed, such as from brown to violet in the case of nickel, from pink to blue in the case of cobalt, and the progressive development of the colour of copper, all brought about by increasing the proportion of alkali, appeared to point to something like a separation of the oxides of those metals, if not a definite separation. With very little alkali present, the coloured oxides might be playing a basic part, but as the proportion of alkali was increased they might be freed or caused to play an acid part. F. W. H.

7. Production of Selenium Red Glass. F. A. Kirkpatrick and G. R. Roberts (*J. Amer. Cer. Soc.*, 1919, **2**, 895).—Thirty pounds of batch were melted in closed pots at 1400°. The batch was introduced in three fillings over a period of three hours, and the melting and fining occupied eight hours. Then the metal was allowed to cool during half an hour to working temperature, and the working out occupied two or three hours. To prevent the escape of volatilised selenium from the pots, the pot stoppers were covered with wet clay. Prior to working out, the metal was skimmed, the skimmings being used as cullet.

Melts were made of a soft working zinc–alkali glass and a plate glass, the formulæ and batches for which were as follows:—

Zinc-alkali glass.				Plate glass.			
Formula.		Batch.		Formula.		Batch.	
SiO_2	2·26	Sand	100·0	SiO_2	2·62	Sand	100·0
K_2O	0·239	Potash	30·3	Na_2O	0·427	Soda-ash	29·8
Na_2O	0·408	Soda-ash	30·3	CaO	0·549	Hydrated lime	27·7
ZnO	0·353	Zinc oxide	21·2	CdS	0·015	Cadmium sulphide	1·35
CdS	0·0142	Cadmium sulphide	1·51	Se	0·020	Selenium	1·04
Se	0·026	Selenium	1·51	MgO	0·024		
B_2O_3	0·0145	Borax	1·51				

The glass was gathered on punties and worked by pressing or blowing in a mould, or by blowing without press or mould. The use of the three different methods determined the operations necessary for the development of the correct colour.

It was found that the method of working was a most important factor in the production of selenium red glass. Escape of selenium throughout the whole melting and fining period must be prevented, and the glass must be allowed to cool immediately after gathering for a sufficient length of time, usually from half to one minute, and from pot temperature to from 400° to 700°, in order to bring the selenium into the proper state of dispersion for the subsequent development of the red colour by re-heating. Pressed ware gave the best colour when heated, after pressing, for a period from one to five minutes at 900°. Sometimes articles blown in a mould developed colour before being placed in the lehr, and sometimes afterwards. By purely hand-working methods, decanter-shaped vases, 6 inches to 12 inches in height, were made from both kinds of glass. The plate-glass vases tended to give a sealing-wax-red colour, probably due to crystallisation. The zinc–alkali glass vases did not give this result normally, but crystallisation could be produced by heating for thirty minutes at 900°. In both cases the colour developed during working, before being placed in the lehr.

Temperatures of glory-holes and lehrs were given, and details tabulated of the time taken for each separate operation, and diagrams were given showing the effect of specimens on the prismatic solar spectrum. The following were typical tables:—

Pressing in a Mould.

Zinc Glass Lenses, 3 *Inches in Diameter.*

Time in seconds from instant of gathering.	Stage of process.
0 to 2	Glass gathered from pot.
2 ,, 20	Glass marvered (rolled on iron plate).
20 ,, 40	Lens pressed in mould.
40 ,, 60	Lens allowed to cool.
60 ,, 120	Lens flashed in glory-hole.
120 ,, 130	Lens allowed to cool.
130	Lens placed in lehr.

Blown in a Mould.

Time in seconds from instant of gathering.	Stage of process.
0 to 2	Glass gathered.
2 ,, 30	Glass blown and worked to shape in iron blocks.
30 ,, 130	Glass bulb allowed to cool until dark (about 400°).
130 ,, 200	Glass bulb flashed in glory hole.
200 ,, 230	Salt shaker blown and held in mould.
230 ,, 240	Salt shaker placed in lehr.

Making of Vases.

Time in seconds from instant of gathering.	Stage of process.
0 to 3	Glass gathered on punty.
3 ,, 8	Glass bulb blown and swung to length.
8 ,, 30	Bulb marvered.
30 ,, 40	Bulb blown to a larger size.
40 ,, 45	Bulb swung to length.
45 ,, 50	Bulb taken to work bench.
50 ,, 60	Neck cut in bulb.
60 ,, 75	Bulb swung to length.
75 ,, 90	Bottom of bulb softened in glory hole.
90 ,, 110	Vase shaped by allowing it to stretch and by pressing the bottom against an iron plate.
110 ,, 125	Bulb of vase blown to larger size.
125 ,, 140	Bottom shaped by pressure of tool.
140 ,, 150	Vase heated in glory-hole.
150 ,, 180	Bottom again shaped.
180 ,, 185	Bottom of vase stuck to another punty.
185 ,, 225	Top of vase heated in glory-hole.
225 ,, 230	Vase swung and revolved to straighten neck.
230 ,, 250	Vase rotated on punty and top of neck flared with tools.
250 ,, 270	Vase allowed to cool to just below red heat.
270 ,, 275	Vase broken off punty.
275 ,, 280	Vase placed in lehr.

F. W. H.

8. Selenium as a Colouring Agent for Soda-lime–Silicate Glasses. P. Fenaroli (*Chem. Zeit.*, 1912, **36**, 1149, and 1914, **38**, 177).—In order to investigate the action of selenium as a colouring agent, the author made special melts based on the formula $6SiO_2,CaO,2Na_2O$ in porcelain crucibles. The glass took from twenty-four to thirty hours to clear at about 1400°. When each melt was clear, finely powdered selenium element was added, the proportion varying from 0·05 to 0·2 part of Se to 100 parts of sand. When the glass was once again clear, the crucible was covered and the furnace closed, in order to prevent oxidation, and the whole allowed to cool very slowly. The proofs of all the melts, taken before closing down, were almost colourless. The final products, obtained by slow cooling, were also colourless when viewed by transmitted light, but exhibited a blue fluorescence, which increased as the selenium content increased. Examination of the glasses by the ultramicroscope showed this fluorescence to be due to colloidal particles in the case of the glasses rich in selenium, but submicrons could not be distinguished in those which only contained a small quantity.

The meltings were then repeated, with the addition of 0·5 part of charcoal to 100 parts of sand in each melt, in order to ensure reducing conditions. The proofs before the addition of Se were again colourless. The addition of selenium produced a deep reddish-brown colour, which was very intense even with the smallest quantity added. The intensity of the colour increased relatively little with larger selenium content. The blue fluorescence previously observed was again present when the selenium content was large, though not to such a great degree. Those glasses with little selenium were again optically clear, even though intensely coloured. The richer ones again contained colloidal particles.

An absorption spectrograph of the red glass showed absorption from $\lambda = 424\ \mu\mu$ to $\lambda = 505\ \mu\mu$. This was the same as was obtained with selenium hydrosols and aqueous solutions of sodium and potassium polyselenides. Further, all the glasses when dissolved in HF, in an atmosphere of CO_2, gave H_2Se, metallic Se being precipitated. This supported the view that selenides were present.

In the second paper further investigations were described. In these experiments the glass was melted at a temperature of 1530°, taking six to seven hours to clear, and being cooled down after nine hours. A reducing atmosphere was obtained in the furnace, rendering the addition of charcoal unnecessary. 0·1 part of Se was added for every 100 parts of silica, and the proof was a bright salmon colour. The slowly cooled glass was feebly flesh-coloured, milky, and quite opaque, even though several melts were carried out. The transparent glass gave H_2Se and Se with HF; the milky glass gave H_2Se, but very little Se. The former was not optically clear, but the diffraction cones were reddish-violet and not sky-blue, as previously. The colour more nearly resembled that of the commercial red glasses than the previous specimens had done. The slowly cooled glass was a suspensoid with sky-blue diffraction cones.

The same amount of selenium was added to a glass of the composition of $9SiO_2,CaO,1{\cdot}66Na_2O,0{\cdot}33K_2O$, and similar colour effects were observed, but in this less basic potash glass a purer red was obtained than with the more basic soda glass. It was noted that Le Blanc had found when selenium was dissolved in a concentrated KOH solution, a mixture of selenides and selenites was formed, and when the solution was diluted, selenium element was precipitated.

The author concluded that the various glasses obtained were coloured in the following ways. The brownish-red, optically clear glasses obtained by energetic reduction contained polyselenides as pigment. The straw-coloured glasses, produced when the reduction was only partial and when the metal was slowly cooled, contained selenides and selenites. The selenites, being only slightly soluble in the glass, produced opalescence, and the selenides coloured the glass. The commercial red glasses obtained by preventing a too slow cooling contained colloidal selenium as pigment. This was formed at high temperatures by the dissociation of the sodium polyselenide formed at the beginning of the melt, and as the glass was fairly rapidly cooled, it could not change back into the selenide. This took place, with slow cooling, according to the equation $3Na_2O + (2n+1)Se = 2Na_2Se_n + Na_2SeO_3$, the change going to the left at high temperatures and to the right at relatively low ones. This explained the cloudiness of the slowly cooled glasses, which were otherwise red.

The red glasses contained submicrons less than $40\ \mu\mu$ in length, and the general properties of these colloidal solutions corresponded accurately with those of other selenium sols. The glasses also bore a marked resemblance to Hoffmann's "ultramarines." A glass was melted to the formula 3·6 grams of borax, 0·01 gram of Se, and 2·2 grams of boric acid (that is, approximately Na_2O,B_2O_3) to illustrate this resemblance. The proof was transparent yellow; when the glass was cooled to about 800°, it was purplish-red, and when cooled to 500° it was dirty red and cloudy. Thus the soda-lime–silicate glasses and the "ultramarines" were very much alike, and probably their constitutions similar. J. R. C.

9. Tellurium as a Colouring Agent for Soda-lime–Silicate Glasses. P. Fenaroli (*Chem. Zeit.*, 1914, **38**, 873).—The experiments followed the same course as those referred to in the preceding abstract. The preliminary melts, without the addition of charcoal, and without special precautions to ensure a reducing furnace atmosphere, yielded proofs which were almost colourless, the slowly cooled mass being also without colour. The addition of charcoal caused an uneven colouring, even with little tellurium. The greater part of the mass was brown, but in some places it was a dirty olive-green when viewed by reflected light. When the tellurium concentration was great, the irregularity of the colouring increased; in some places it was coral-red, in others sky-blue, and in others brown. None of these glasses was optically clear. Tellurium hydrosols behaved in the same way, and the absorption spectra of the glasses were similar to those of the hydrosols. An analogy with Hoffmann's "ultramarines" was again remarked. When treated with HF, the glasses yield H_2Te and precipitated tellurium, indicating the presence of polytellurides. It was concluded that the action of tellurium was to be explained in the same way as that of selenium. J. R. C.

10. The General Behaviour of the Elements Sulphur, Selenium, and Tellurium in Soda-lime–Silicate Glasses with Particular Reference to the Colour Produced. P. Fenaroli (*Kolloid Zeitsch.*, 1915, **16**, 53).—The experiments referred to in the two preceding abstracts had led to the conclusion that the elements of this group were only effective in colouring glasses when they are present either as colloidal elementary solutions or as polysulphides, polyselenides, or polytellurides of the metals in the glasses, probably of the alkali metals. As the polysulphides, selenides, and tellurides did not differ greatly from solutions of the elements in the monosulphide, selenide, and telluride, the colouring effect might be attributed to the elements themselves, the various colours obtained depending on the manner of solution, or, more accurately speaking, on the degree of dispersion of the elements in the solution.

The glasses coloured by sulphur were first considered. If the glass contained only a small amount of heavy metal, a yellow or yellowish-brown colour was produced, the glass being optically clear.

The colour was due to the sulphide, with excess of sulphur, probably also to polysulphides, as it was the same as that exhibited by an aqueous solution of the alkaline polysulphides, which contained highly dispersed sulphur. The strongly electronegative character of sulphur did not permit it to exist in any other state than that of a true solution in the sulphide when the glass was an alkali-lime glass of ordinary composition melted under reducing conditions. Hence the colour could not vary. In a soda–borate glass, which was of a more acid character, the possibility of the presence of free sulphur was greater, and blue glasses might be obtained.

Selenium was of a less electro-negative nature than sulphur, and thus it was possible for it to be present in the elementary condition even in the soda-lime–silicate glasses. With very alkaline glasses and strongly reducing conditions, in this case, also, the chestnut-brown colour obtained was due to a true solution of the selenide or polyselenides. In glasses where the alkalinity was not too pronounced and the reducing conditions during melting not too strong, the greater part, if not all, of the selenium might be dissociated and form a colloidal solution, red and other coloured glasses being obtained. As the colour depended on the size and dispersion of the submicrons, it was affected by the rate of cooling, as above described. The colourless glasses sometimes obtained were due to the presence of the selenium in a very high degree of dispersion, probably molecularly dispersed. The author considered that the purer red produced when potash was used instead of soda was due to the greater viscosity of the potash glasses. This caused an increase in the dispersion of the submicrons, and consequently the transmitted light was redder. If a selenium soda–borate glass was maintained for a long time in the molten condition at a low temperature, it changed from yellow to red, and became more red the longer it was kept in that state.

Tellurium was still less electro-negative than selenium, and therefore it was easier to get it in the elementary condition in soda-lime–silicate glasses. Its irregular behaviour had prevented any relation being established between the colour and the tellurium concentration, but it was considered not improbable that a colloid-disperse substance was formed which had no direct influence on the colour. J. R. C.

11. The Colours of Colloids, Glasses, Glazes and Gems. W. D. Bancroft (*J. Physical Chem.*, 1919, **23**, 603, 623). —When glasses were coloured by some metals, for example, gold, silver, and copper, examination by the ultramicroscope showed them to be colloidal and to possess the characteristics of colloidal solutions. When a gold-containing glass was quickly cooled it was colourless, a red colour being developed by re-heating, and if kept too long at a high temperature a blue colour was observed. This last appeared to be due to the coagulation of the colloidal particles. The colourless glass was difficult to explain. It was probably due to the presence of the gold in a true solution or to its particles being too small to have an optical effect. Zsigmondy preferred the former explanation.

In the case of copper ruby glass, Seger had stated that it was not due to precipitation of metallic copper, as, in order to obtain the best red glaze, alternate oxidising and reducing conditions were necessary. Stokes had optically examined a glass coloured red by copper in a very thin stratum on one face, and concluded that a small proportion of the copper was present in a state of suboxide, or as a silicate of this base, and the rest was metallic copper. Zulkowski thought the red due to cuprous oxide, but the general consensus of opinion was against him. Zsigmondy pointed out that though copper hydrosols were red and cuprous oxide hydrosols orange, anhydrous cuprous oxide was red, and it was probable that an anhydrous colloidal solution of cuprous oxide would also be red. If the copper was present in the cuprous state it must be as oxide, because cuprous silicate, even though it might be red, would give an optically clear glass. The question arose whether or not cuprous oxide could exist in glass.

The yellow stain produced by firing a glass with silver was due to finely divided colloidal silver. It was best obtained with potash–lime glasses. With "hard" glasses, the silver tended to be deposited metallically. Platinum and iridium oxides could be used to give grey colours, and suspended carbon gave rise to yellow.

Glasses containing no heavy metals were coloured yellow by sulphur, the colour being due, apparently, to polysulphides. More acid glasses might be coloured blue by colloidal sulphur (see preceding abstracts). Glasses could be coloured yellow by colloidal cadmium sulphide. At certain concentrations of some colouring oxides, a second phase appears. Thus it was possible to make a chrome-aventurine glass in which the second phase could be seen, though it was not known whether or not it was chromium oxide or a chromium silicate.

In general, glasses coloured by silicates of iron, copper, manganese, and cobalt were optically empty, but as stannic oxide, zirconia, titania, magnetite, and probably cuprous oxide could exist as second phases under certain conditions, this might not be universally true, so the colours produced by these common colouring agents were examined. Iron usually produced a yellow or green colour in glasses and glazes, but in some cases the latter were coloured red through the iron being present as ferric oxide, and not in solution. Both cobaltic and cobaltous salts gave rise to a blue colour. Nickel, manganese, and iron turned this blue to a greyish-blue. With cobalt and chromium, all shades of bluish-green could be obtained. Manganese coloured glass in various tints from amethyst to violet. The individual effects of the various manganese oxides had not yet been ascertained, though it was probable that manganese oxide took up oxygen to form the peroxide, losing this oxygen again on fusion. Wicks and Mellor had found that nickel glazes could be blue, green, yellow, or brown, according to the composition of the glaze. Nickel oxide melted with basic oxides only, or with silica only gave colours varying from pale brown to dark olive-green.

Granger found that copper coloured lime–soda and lime–potash glasses blue, the colour changing to green as the concentration increased. This was not the general experience, as most investigators said that the colour was green with soda glasses and blue when potash was used, the effect being analogous to that produced by iron, which, in the ferrous condition, gave a bluer tint with potash than with soda. Glasses rich in silica tended to give a green colour with copper, whilst large lime content appeared to be most favourable for the production of red copper glasses. The author pointed out that it was not known how the pink colour was caused when manganese or chromium were added to the batch, and that the nickel colours were still unexplained. He was of the opinion that the mechanism, by means of which glasses were coloured, when melted with various oxides, was in need of systematic investigation.

In the paper dealing with gems, the author showed that the position was still more uncertain. Very little was known concerning the agents which produced the colour. Probably it was frequently due to organic compounds. The most extensive investigations on the colours of gems were those of Doelter, who exposed them to the rays from radium and to ultra-violet light. No attempt was made to explain the changes observed. The author concluded from the results obtained that the effect of radium rays was the reverse of that produced by ultra-violet light. The whole subject, however, called for further research. J. R. C.

12. The Production of Opal Glass without Cryolite. (*Sprechsaal*, 1919, **52**, 30, 265).—As substitutes for cryolite in the manufacture of opal glasses, tin oxide, Baker guano, fluorspar, and bone ash were mentioned. Tin oxide was expensive. Successful opal glasses could be made, using either bone-ash or felspar–fluorspar mixtures as opacifying agents. Typical batches described are as follows:

	I.	II.
Sand	100·0	100·0
Potash....................	10·0	2·5
Soda ash	24·5	27·5
Limespar	18·0	—
Bone ash..................	22·0	1·5
Borax	2·0	—
Saltpetre	2·0	—
Fluorspar	—	11·0
Felspar	—	27·5

J. H. D.

13. Light Cast Plate Glass. (*Sprechsaal*, 1919, **52**, 27, 227).—Cast plate glass had the particular advantage over the so-called "three-quarter white" glass (blown) that it could be made in sheets as large as 20 sq. m., whereas it was difficult to make plate glass on the blowing iron in sheets larger than 1 sq. m. On the other hand, cast plate glass was usually made in thickness from 9 to 10 mm., so that if glass of similar quality was required but 3—4 mm. thick, an inordinate amount of grinding was necessary. Thin plate could be made by the Fourcault process,* but apart from its inferior quality it was not sufficiently regular in thickness to allow of it being used with advantage for mirrors.

Two methods were briefly described for the production of light plate glass. At Herzogenrath, large pots were used, and sheets of 50—60 sq. m. surface and 7 mm. thick were cast and rolled in the customary manner, but using much larger casting tables and heavier rollers. Immediately after rolling out, the sheet was cut up into suitably sized pieces and taken to the annealing oven. Grinding and polishing took place after annealing in the same manner as with thick plate. Casting took place once daily in each furnace, and the quality of the product was very good.

In the second or "three-quarter white" method, much smaller pots were used. The furnace contained 20 pots yielding sheets varying from 4 to 10 sq. m. of good glass of a thickness of 7 mm. To obtain increased production and economy the melting was arranged so that two casts were made from each pot in twenty-four hours. Although a considerable proportion of the glass produced was not good enough for mirror plate, yet considerable success had attended this method of working. Comparing the various systems of producing plate glass, the author mentioned that light cast glass (as above) did not require skilled glass-blowers for production. Not only was this of importance on account of the high wages earned by skilled plate glass-blowers, but more particularly since the supply of skilled workmen in this particular branch of the industry was diminishing. Very much larger sheets could be cast than blown on the pipe. Further, for equal fuel consumption, the amount of light cast glass produced was from one and a-half times to twice as much as the amount of blown glass. There was much more inferior glass produced by the light cast method than by blowing, but this was more than balanced by the greater economy in manufacture, particularly as inferior qualities were at present in considerable demand for glazing. Heavy cast glass (12 mm.) had the one advantage over light cast glass that it could be made in larger sized sheets.

The capital outlay was stated to be greater for the Herzogenrath method, but it was a much cheaper method in operation than the three-quarter white method for the production of light cast glass.

J. H. D.

14. Note on the Borates of Lead. H. V. THOMPSON (*Trans. Eng. Cer. Soc.*, 1918—1919, ii, 510).—An investigation of the identity of the four borates which it is asserted lead forms. The author gives details of these borates, namely, (1) metaborate, $Pb(BO_2)_2,H_2O$; (2) polyborate, $2PbO,3B_2O_3,4H_2O$; (3) $PbO,2B_2O_3,4H_2O$; and (4) $PbO,3B_2O_3$.

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* It can be made by the Libbey-Owens (or Colburn) process.—W.E.S.T.

He confirmed the existence of $Pb(BO_2)_2,H_2O$ and $PbO,3B_2O_3$, but found no support for the formation of any definite chemical compounds having formulæ $PbO,2B_2O_3,4H_2O$ or $2PbO,3B_2O_3,4H_2O$.
C. M. M.

15. The Formation of Silicates, Glasses, and Glazes. J. W. Cobb (*Proc. Chem. Soc.*, 1909, **25**, 165).—On the assumption that the formation of a glass was brought about by the combination and solution of the constituent oxides, the author investigated the formation of the glass represented by the formula

$$Na_2O,CaO,Al_2O_3,10SiO_2.$$

Lime and silica were found to combine, producing the compounds $2CaO,SiO_2$ and CaO,SiO_2.

Lime and alumina formed compounds CaO,Al_2O_3, $CaO,2Al_2O_3$, and an insoluble calcium aluminate, presumably containing a great quantity of alumina.

Three conclusions were drawn from the study of the chemical interaction between solids. (1) The temperature of formation of a slag and its fusion point were not identical, nor apparently related, and this opposed Boudouard's generalisation. (2) The interaction between solids might proceed far, even to completion, without fusion. (3) From a temperature of 800° upwards the state of mixed solid particles was one of fairly effective molecular contact, allowing free play to selective chemical affinities. V. D.

16. The Influence of the Composition of Glass on Pharmaceutical Preparations. A. Lesure (*J. Pharm. Chim.*, 1910, **1**, 66—71 and 119).—Solutions of easily hydrolysable substances, such as cocaine salts, should be kept in vessels made of neutral glass, which should show no sign of alkalinity with Poulenc's alizarin sulphonate reagent when heated with water in an autoclave at 120° for twenty minutes. A non-calcareous glass containing alumina, zinc, and magnesia as bases should be used for holding solutions of such salts as phosphates and arsenates, which gave precipitates with lime. More stable salts, such as sodium cacodylate, methyl arsenate, strychnine salts, and mercury salts could be kept in vessels made of glass showing faint alkalinity if this did not exceed the equivalent of 5 c.c. of $N/100NaOH$ per 100 c.c. of capacity, after thirty minutes in the autoclave at 120°. Solutions of iodides, bromides, and chlorides must not be stored in lead glass containers.

Almost all medicinal chemicals could be heated in an autoclave at 120° in containers of neutral glass, without decomposition taking place. V. D.

17. On Devitrification. W. Guertler (*Zeitsch. anorg. Chem.*, 1904, **40**, 268).—The author studied the conditions for devitrification of sodium metasilicate, cobalt pyroborate, copper metaborate, and manganese diborate with the idea of illustrating and testing the views of Lammann on the theory of devitrification. The borates of cobalt and copper were melted and quenched in a fine stream by running into water. The quenched material was powdered and packed, in a platinum crucible, round the junction of a thermocouple. The manganese borate and sodium metasilicate, being found capable of ready supercooling, were cooled rapidly to form glasses with the thermo-element in position. Subsequently, the crucible in each was slowly heated, and the temperature noted at which rapid rise of temperature began, due to crystallisation occurring, accompanied by liberation of heat, and the maximum temperature attained also recorded. The sodium metasilicate and manganese diborate glasses had to be inoculated, since they contained, apparently, no crystal nuclei like the two other borates.

The temperature at which devitrification began (t_d) and t_m, the melting point of each compound, were as follows:

	t_d.	t_m.
Na_2SiO_3	550±20°	1055°
$Co_2B_2O_5$	640±20°	1025°
CuB_2O_4	675±15°	980°
MnB_4O_7	670±20°	895°

When once the rise of temperature began at t_d, its rate increased very rapidly. The value of t_d was found to be independent of the rate of external heating. W. E. S. T.

18. The Softening Temperatures of Lead-Silica Glasses.

J. W. Mellor, A. D. Holdcroft, and A. Latimer (*Trans. Eng. Cer. Soc.*, 1909—1910, **9**, 126).—From consideration of the cooling curves illustrating the behaviour of silicates cooling from the molten to the rigid state, the authors state that glasses and glazes may best be defined as undercooled solutions. If no crystallisation takes place there is no critical temperature above which it can be said that glass is a mobile fluid and below which it becomes a rigid solid. In other words, glasses have no true melting point, but their mobility increases as the temperature is raised, and their viscosity increases as the temperature is reduced.

The softening temperature of a glass is defined as the range of temperature where a substance begins to lose its shape and flow like a liquid, and the determination of this temperature resolves itself into the measurement of a certain stage in the diminishing viscosity of the glass when its temperature is increased at a given rate. Five methods of ascertaining this range of temperature were given, namely, (1) the squatting of pyramids or cones of standard composition; (2) the sinking of a rod in the softening substance; (3) the dropping of a portion of the substance from a wire heated to a known temperature; (4) the development of electrical conductivity sufficient to allow a given electric current to pass through the substance; (5) observation of the rounding of corners or melting of fragments under the microscope under steadily rising temperatures.

The authors discussed the molecular theory of softening at elevated temperatures, and arrived, on theoretical grounds, at the following deductions, which were supported by practical observations: (*a*) The softening temperature measures the temperature at which the inward surface pressure of the substance becomes greater than those intermolecular forces which hinder the molecules taking up the position of stable equilibrium, that is, of minimum surface area. (*b*) The softening or melting of the surface of different substances takes place at a lower temperature than the softening or melting of the substance in lump. (*c*) With particles having a relatively large surface area in proportion to their mass, the finer the grain the lower the softening temperature. (*d*) Two "solid" substances may react at temperatures considerably below the melting point or softening temperature of either alone.

Numerous determinations of the softening point of many lead–silica glasses were made, using the fifth method mentioned above. Details of the method employed and the apparatus used were given. The results were plotted as a curve showing that (1) the melting point of pure PbO is 877°; (2) the addition of gradually increasing quantities of silica rapidly lowers the melting point of the corresponding glasses to a minimum of about 526°, corresponding with a glass of the composition PbO : $0{\cdot}21SiO_2$ (about 95 per cent. PbO); (3) beyond this minimum the softening temperature of the glasses gradually increases with increasing silica, reaching 661° with a glass of the composition PbO : $2{\cdot}4SiO_2$ (60·6 per cent. PbO); (4) the determination of the softening temperatures of glasses very rich in lead (92—95 per cent. PbO) is disturbed by crystallisation. By comparison with results obtained by other investigators, it was noted that the melting point of the lead–silica glasses is considerably below that of the same silicates in the crystalline condition (generally about 200°).

Curves were given showing the effect on the softening point of lead monosilicate glasses of gradually increasing amounts of copper oxide, ferric oxide, and cobalt oxide. In each case a gradual rise in the softening temperature of the glass was observed as the amounts of the colouring oxide were increased until a maximum was attained. Further additions reduced the softening temperature again. With copper oxide, the softening point of the lead silicate was increased from 535° to 560°, corresponding with the addition of 3 per cent. CuO. The addition of more CuO reduced the softening point of the glass again until with 6·9 per cent. of CuO it was again 535°. In the case of ferric oxide the maximum (560°) was attained with the addition of 1·0 per cent. Fe_2O_3. With 7 and 14 per cent. of Fe_2O_3 the softening point of the glass was reduced to 538°. The addition of 4 per cent. of cobalt oxide raised the softening point of the glass from 535° to 602°. Further additions lowered this again to 567° with 6·6 per cent. CoO.

The authors noted that these figures had no known relation to the subsequent behaviour of the softened mass, and it was known that the addition of some oxides made more mobile fluids than others.

J. H. D.

19. On the Density of Silicate Mixtures. E. Ward Tillotson (*J. Ind. Eng. Chem.*, 1911, **3**, 897).—The paper gives the results of the examination of the accuracy of Winkelmann and Schott's density factors for the calculation of the density of glasses, and sets out new factors which appear to lead to closer agreement between calculated and observed results. The experimental data used by the author were those previously derived by Larsen during a study of calcium and magnesium metasilicates, by Wallace for lithium–barium and lithium–calcium silicates, and by Day and Allen for some mixed felspars.

Table I.

Percentage.				Density.		
$CaSiO_3$.	CaO.	MgO.	SiO_2.	Obs.	Calc.[1]	Calc.[2]
100·0	48·20	0·00	51·80	2·904	2·698	2·920
95·0	45·80	2·01	52·19	2·899	2·700	2·910
85·26	41·09	5·91	53·00	2·891	2·701	2·897
74·0	35·70	10·43	53·87	2·881	2·706	2·879
64·0	30·84	14·43	54·73	2·872	2·709	2·863
60·0	28·92	16·04	55·04	2·859	2·711	2·855
53·64	25·85	18·59	55·56	2·854	2·713	2·848
40·0	19·28	24·06	56·66	2·834	2·718	2·829
30·0	14·46	28·07	57·47	2·821	2·722	2·815
10·0	4·82	36·09	59·09	2·780	2·730	2·787
5·0	2·41	38·10	59·49	2·777	2·733	2·780
0·0	0·00	40·10	59·90	2·758	2·735	2·773

The densities tabulated under Calc.[1] were calculated from Winkelmann and Schott's factors, namely, SiO_2, 2·3; CaO, 3·3; and MgO, 3·8; those under Calc.[2] from the author's new factors, namely, SiO_2, 2·3; CaO, 4·1; MgO, 4·0.

As tabulated in table I and also when plotted on curves, the observed results and those under Calc.[1] are at one end of the series widely divergent.

Tables II, III, and IV contain the results for other glasses examined.

Table II.

Lithium–Barium Glasses.

Percentage.				Density.	
$BaSiO_3$.	Li_2O.	BaO.	SiO_2.	Obs.	Calc.[2]
0	33·30	0·00	66·70	2·61	2·63
10	29·97	7·18	62·85	2·70	2·74
20	26·64	14·36	59·00	2·80	2·87
30	23·31	21·53	55·16	2·91	3·00
40	19·98	28·71	51·31	3·17	3·14
50	16·65	35·89	47·46	3·38	3·31
60	13·32	43·06	43·62	3·50	3·48
70	9·99	50·24	39·77	3·77	3·69
80	6·66	57·42	35·92	4·02	3·91
90	3·33	64·60	32·07	4·19	4·16
100	0·0	71·78	28·22	4·44	4·44

TABLE III.

Lithium–Calcium Silicate Glasses.

Percentage.					Density.		
$CaSiO_3$.	Li_2O.	CaO.	SiO_2.		Obs.	Calc.[1]	Calc.[2]
0	33·30	0·00	66·70		2·61	2·63	2·63
10	29·97	4·82	65·21		2·64	2·63	2·65
20	26·64	9·64	63·72		2·69	2·64	2·69
30	23·31	14·46	62·23		2·72	2·65	2·71
40	19·98	19·28	60·74		2·76	2·66	2·74
50	16·65	24·10	59·25		2·80	2·66	2·77
60	13·32	28·92	57·76		2·80	2·67	2·80
70	9·99	33·74	56·27		2·84	2·68	2·83
80	6·66	38·56	54·78		2·85	2·69	2·85
90	3·33	43·38	53·29		2·88	2·69	2·88
100	0·0	48·20	51·80		2·91	2·70	2·92

In the above calculations of density, Winkelmann and Schott's factors were used for SiO_2 and BaO in both sets of calculations, namely, SiO_2, 2·3, and BaO 7·0. The author's modified value for CaO was employed in the results in the last column, and his value for Li_2O, namely, 3·7.

TABLE IV.

Percentage.					Density.		
SiO_2.	Al_2O_3.	CaO.	Na_2O.		Obs.	Calc.[1]	Calc.[2]
43·33	36·60	20·06	0·11		2·700	2·980	2·700
47·10	34·38	17·00	1·74		2·648	2·880	2·644
51·06	31·72	13·65	3·68		2·590	2·820	2·600
60·01	25·24	7·09	7·79		2·486	2·680	2·497

Instead of Winkelmann's factor for Al_2O_3, namely, 4·1, the new value 2·75 was derived and used.

The new factors derived by the author were further tested by application to several Jena glasses, and proved to yield much more concordant results than obtainable by Winkelmann and Schott's factors.
W. E. S. T.

20. The Relation of the Refractive Index of Soda–Lime Glasses to their Chemical Composition. E. W. TILLOTSON (*J. Ind. Eng. Chem.*, 1912, **4**, 246).—In order to test the nature of the relationship between the refractive index for white light and the composition of a glass, the author prepared on a small scale in clay pots a series of soda–lime glasses, of composition ranging from $Na_2O,3SiO_2$ to CaO,SiO_2.

Table I contains the statement of the percentage composition of the glass, based, not on the analysis of the glasses, but on the original batch compositions, together with the values of *D*, the density calculated with an average error of 1 per cent., *N* the refractive index, and *K* (obs.) and *K* (calc.) described further below.

TABLE I.

$CaSiO_3$ mol. per cent.	SiO_2.	CaO.	Na_2O.	*D*.	*N*.	*K*(obs.)	*K*(calcd.)
0·0	74·45	0·00	25·55	2·37	1·5000	0·2110	0·2110
10	73·60	2·50	23·90	2·395	1·5060	0·21127	0·2111
20	72·30	5·18	22·50	2·42	1·5115	0·21137	0·2112
30	70·85	8·25	20·90	2·45	1·5172	0·21110	0·2112
40	69·30	11·70	19·00	2·48	1·5240	0·21129	0·2113
50	67·40	15·60	17·00	2·52	1·5334	0·21166	0·2115
60	65·20	20·20	14·60	2·57	1·5432	0·21137	0·2116
70	62·75	25·35	11·90	2·63	1·5590	0·21254	0·2127
80	59·60	31·80	8·60	2·70	1·5800	0·21442	0·2142
100	51·85	48·15	—	2·92	1·628	0·21517	0·2178

The value of K (obs.) is that of the specific refraction determined from the formula of Gladstone and Dale, namely, $N-1/D$. K (calc.) was derived by plotting the values of K (obs.) against the percentage by weight of $CaSiO_3$ present; in other words, K (calc.) represented smoothed values.

The specific refractions were also calculated by the Lorenz and Laurentz formula, namely, $\frac{N^2-1}{N^2+2} \times \frac{1}{D}$. In both methods of calculation it was found that when the results were plotted graphically the curve was linear, with a sharp change of direction occurring at the composition $2Na_2O,3CaO,5SiO_2$, and a compound of this composition was assumed to be indicated.

It was found that the specific refractivities, calculated by either formula, could be represented by the following expression:

$$K = \frac{p_1k_1}{100} + \frac{p_2k_2}{100} + \frac{p_3k_3}{100},$$

where p_1, p_2, and p_3 are the percentage amounts of SiO_2, CaO, and Na_2O present in the glass, and k_1, k_2, and k_3 the specific refractivities of these oxides respectively. From the results the values of specific refraction for these oxides are: SiO_2, 0·1220; CaO, 0·1210; and Na_2O, 0·1302, the Lorenz and Lorentz formula being made the basis of the calculation. W. E. S. T.

21. Some Aspects of Scientific Research in Relation to the Glass Industry. E. W. WASHBURN (*J. Amer. Cer. Soc.*, 1919, **2**, 855).—The necessity for fundamental research in the glass industry was emphasised most particularly, and many of the pressing problems were indicated. These included the determinations of viscosity, surface tension, vapour pressure and density of molten glasses, the relation between viscosity and temperature being intimately connected with stirring, gathering, drawing, and blowing, whilst the process of fining was very closely connected with the viscosity, surface tension, and vapour pressure. The substitution of soda for potash in optical glasses was impracticable, owing to increased colour, but it was necessary to discover to what agency this increased colour was due. Scarcely anything was known concerning the gases which remained in solution in glass or concerning the electrical conductivity of glass and its relation to composition. In addition to such problems as these, there was an almost infinite number of purely scientific problems.

There were three types of laboratories in which these researches might be carried out: research laboratories of the industry itself, Government laboratories and laboratories of research foundations, and laboratories of university ceramic departments. Though the industry was not entirely dependent on the universities for research, it was dependent upon them for the training of its technical *personnel*. Such training was the most expensive which a university gave, and if the glass industry desired this training to go on, some way of providing financial assistance must be found, for no university with a ceramic department at the present time was financially able to extend its activities. F. W. H.

III.—Lamp-worked and General Scientific Apparatus.

22. The Construction of Silica Glass Articles. W. S Quimby and F. W. Robinson, U.S.A. (Brit. Pat., February 5th, 1919, No. 2866).—Relates to building up articles of quartz glass by heating an initial nucleus of quartz glass to a plastic condition and causing powdered quartz to adhere to it, the powder being afterwards melted so as to coalesce with the nucleus. Fig. 3 shows one end of the apparatus used. The tubular or solid nucleus, *A*, is held in chucks, *B′*, and rotated by the gearing shown. It is heated, meanwhile, by a blowpipe, *C*, until it is plastic, when the blowpipe, *C*, is automatically withdrawn and a plate, *D*, carrying powdered quartz, advanced so that some of the powder adheres to the nucleus, *A*. The plate, *D*, is then withdrawn, and the blowpipe, *C*, advanced to melt the adhering powder. These operations are repeated until the article is of the required size. Powder is fed automatically to the plate, *D*, from a hopper, *G*. During the process, the

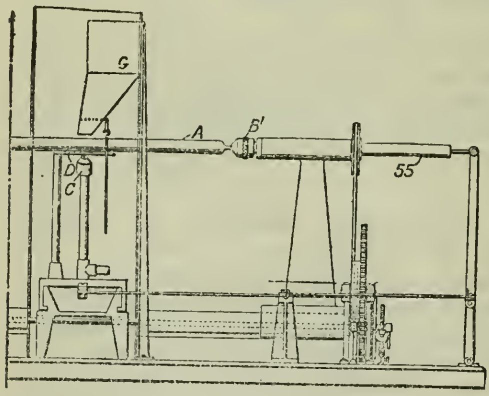

Fig. 3.

chucks, B', are separated slowly, so as to draw out the article and keep the diameter uniform. In the case of a tubular article, the walls are supported by internal air pressure produced by a piston inside the tubular shaft, 55. The diameter may be varied by varying the rate of drawing and internal pressure.

H. G. C.

23. Apparatus for Electrically Sealing High Temperature Mercury Thermometers under Pressure. G. Lips (*Deut. Mech. Zeitung*, 1902, 1).—The thermometer is first evacuated and sealed, and then introduced into an air-tight chamber filled with compressed nitrogen. An iron tube is attached to the thermometer, which is vertical, in order that its height can be adjusted by means of an external magnet. This is done so that the temporary seal can be broken by a blow from a piece of steel, which is also moved by a magnetic arrangement. The thermometer is thus filled with compressed nitrogen, and is then raised so that the head is in an electrically heated tube, which melts the glass, thereby sealing the thermometer. The improvement on previous apparatus for the purpose lies in the method of breaking the temporary seal and introducing the head into the hot tube. A detailed diagram assists the explanation. J. R. C.

IV.—Decorated Glass.

24. Luminous Paints. G. A. H. Muller (Brit. Pat., January 7th, 1919, No. **468**).—A luminous paint is manufactured by heating together sublimed sulphur and carbonates of strontium, calcium, and magnesium. The strontium carbonate is preferably the predominant constituent of the carbonates, the proportions in one example described being sulphur 26 parts, strontium carbonate 19 parts, calcium carbonate 6 parts, and magnesium carbonate 1 part. The mixture is furnaced in a crucible at a temperature of about 1500° F., then ground, and made up into a liquid paint by mixing with a colourless varnish, prepared from mastic and similar gums with turpentine, spirit, or drying oils. H. G. C.

25. A New Method of Coating Pearl Beads. O. Parkert (*Sprechsaal*, 1919, **52**, 23 and 191).—Older methods of coating "pearl" beads were unsatisfactory on account of the ease with which the coating was rubbed off. Better results were obtained by coating the beads with hard varnish containing the "fish silver," but the surface lacked the brilliance of the fire-polished glass. The present process suggested a method for producing the coating on the inside of the beads, thus being protected from abrasion. In the new method, a solution was prepared from dry "fish silver," copal varnish, mastic and acetone, possessing the property of rapid drying. The crystal glass beads were cleaned thoroughly with soda and dried. They were then placed in a glass bowl, so arranged and mounted that it could be rotated rapidly about an inclined axis. A portion of the solution as above was added, the container closed by a rubber cover, and then rotated. After a short period the interior of the glass "pearls" was found to be coated evenly and regularly with the pearl silver, but the excess solution was contained in the interior of the beads as drops of liquid. To remove this, the cover of the vessel was taken off and the speed of rotation doubled, the vessel being gently warmed by a small flame. In a short time the liquid was evaporated, and the coating adhered firmly to the inside of the beads.

Care should be taken that only pure fish scale "silver" (powdered fish scales) is used. If adulterated, for example, with aluminium bronze, the appearance of the resulting "pearls" is not so satisfactory. It was of the utmost importance that the coating solution should be as dense as possible with respect to the "fish silver" without becoming too viscous. Aniline colours and lustres could be applied as interior coatings to beads in a similar manner.

J. H. D.

V.—Optics and Optical Instruments.

26. The Incident Angles Corresponding to Given Deviation produced by a Prism. T. Smith (*Trans. Optical Soc.*, 1919, **21**, 49).—A mathematical discussion providing a formula giving the angle of incidence for a ray which corresponded to a given dispersion when the ray traversed a prism of known refractive index and angle. J. R. C.

27. Spectacles for Aphakic Eyes. T. Chaundy (*Optician*, 1920, **58**, 235).—In view of the fact that it is impossible to correct the astigmatism of a single spectacle lens when the power is greater than 7·25 D+, the author translated, with amendations and explanations, a German patent specification of an invention of Carl Zeiss, dated 1908. The invention claimed was: (1) A collective system for visual use, consisting of two lenses in contact, the power of the contiguous surfaces being positive; the posterior lens being collective and with a concave posterior surface; the system having a large field of view and being astigmatically corrected for a stop about 3 cm. from the last vertex; the anterior lens being also a collective lens. (2) A corrected spectacle system according to claim (1), in which the anterior lens was a meniscus, with its concave surface turned towards the stop. J. R. C.

28. Progress in Manufacturing Radio-protective Glasses. W. W. Coblentz (*Optician*, 1920, **58**, 265).—The ideal protective glass absorbed all the ultra-violet and infra-red radiations, and transmitted only visual rays by an amount sufficient to prevent irritation and injury to the eye. The great demand for colourless optical glass had brought into prominence the colouring effect of iron impurities. In addition to its visible effect, the presence of iron caused marked absorption in the infra-red, which reached a maximum at 1 μ.

Transmission curves of six different types of glass were given by the author. Colourless glasses showed characteristic absorption bands at 2·9 μ and 3·6 μ. Window glass gave also the iron band at 1·1 μ. Red glasses were shown to afford no protection against infra-red rays, though all the ultra-violet was absorbed. Amber glass absorbed the ultra-violet and some of the visible. The iron band was also present. Green glasses were opaque to the ultra-violet, and had the absorption band at 1·1 μ. In combination with other glasses they afforded suitable protection from the injurious rays. As cobalt-blue glass absorbed the infra-red, it was largely used in combination with deep amber, red or green glass for protection when working near sources of ultra-violet radiation. Transmission curves were given of combined red and blue glasses, and of a flashed red, green, and blue set, such as is used in electric welding, and their suitability for the purpose was thus demonstrated. Curves were also given for two Crookes's glasses, namely, sage-green and blue-green; these were shown to be efficient protectors. Gold leaf on glass eliminated the ultra-violet and infra-red, and with the proper density gave adequate protection from glare by visible rays. The protection afforded by black or smoked glasses was insufficient against ultra-violet rays. "Noviweld," a commercial protector, absorbed the ultra-violet and infra-red, but had 10 per cent. transmission bands at 2·5, 3·3, and 3·6 μ.

J. R. C.

29. Description of Three German Naval Gun-sighting Telescopes. J. S. Anderson and A. Barbara Dale (*Trans. Optical Soc.*, 1919, **20**, 315).—The three instruments were a periscopic sight, a right angle sight, and a variable power sight, all made by Carl Zeiss. Photographs of the instruments when dissected, and drawings of the mechanical details and optical systems accompanied the minute but lucid text. The lens-holders of the first two were of hardened steel, the rest of the instruments being constructed from brass and gunmetal, whilst the third was made almost entirely of steel. The inner surfaces of such tubes as would give rise to scattered light had fine screw threads cut in them to diminish the amount of light reflected from them. Elaborate precautions were taken to ensure that the first instrument should be water-tight, but in the case of the second two reliance seems to have been placed on the excellent fit of the different parts. The periscopic sight was provided with a radio-luminous device for illuminating the graticule lens for use in connexion with night-work. All the instruments were provided with detachable spray excluders, and all were fitted with one colourless glass and three colour filters, green, orange, and neutral, the transmission curves of which were described. An analysis of the lubricating grease employed indicated that it consisted of three constituents, namely, beeswax, vaseline, and some other fat, possibly tallow or lard.

The effective aperture of the objective of the periscopic sight was 2·8 cm.; the diameter of the emergent pencil, 0·46 cm.; the magnifying power, 6; and the percentage light transmission, 35. It was a fixed focus instrument. The radii of curvature and dimensions of the eleven lenses which formed the optical system were given. The prism was of the "roof-prism" type, designed to displace the optical axis parallel to itself through 5·5 cm., and to reverse the field. The cross lines of the graticule were engraved on the flat surface of one of the lenses; their thicknesses and separations were given, the former being very uniform.

The effective aperture, the diameter of the emergent pencil, and the magnifying power of the right-angled sight were the same as those of the periscopic sight, the percentage transmission being 38. The radii of curvature and the dimensions of the lenses were tabulated, and the optical data and type of the glass of which these lenses were made were also given. Five of the lenses were of boro-silicate crown, and two, one being part of the objective and the other the graticule lens, were of zinco-silicate crown. The remainder were flints. The light suffered two internal reflections when passing through the prism, and was deflected through 90°, the field being reversed.

The mechanism of the variable power sight was complicated and could not be described without reference to a diagram. The lowest magnifying power was 5 and the highest 15. The instrument had a variable focus. Details of the lenses were given as before, the graticule lens again being a zinco-silicate crown, and not a baryta light flint, as was usual. J. R. C.

30. Description of Goerz Submarine Periscope. L. C. MARTIN (*Trans. Optical Soc.*, 1919, **20**, 338).—The main optical system of this instrument was of the opposed telescopes type, chief interest centring in the part which comprised the eyepiece of the topmost telescope. The optical system of this was described with the aid of a diagram. By means of a lever at the base of the instrument, two additional lenses could be inserted, changing the magnifying power from 6 to 1·5. The graticule was illuminated by luminous paint for night work. The tube of the main periscope system was lined with aluminium pressed up into rings to obviate reflection from the walls of the tube. J. R. C.

31. Description of a German Portable Range-finder. J. S. ANDERSON (*Trans. Optical Soc.*, 1919, **21**, 41).—This instrument was employed for the purpose of measuring the range of an object, of which at least one dimension was approximately known. It consisted essentially of a telescope, in front of the objective of which were two adjacent small-angle prisms cut in the form of discs. One of these was co-axial with the telescope, while the light which passes through the other was deflected by means of a step prism so as to pass into the telescopic system. Thus there were two images of the object in the field of view. The separation of these along a direction parallel to the line joining the centres of the two small-angle prisms could be varied by rotating the prisms till the two images were brought into contact. The range of the object and the angle subtended thereby were then read off scales engraved on a disc which was revolved by the mechanism rotating the prisms, provided that the length of the object was known.

A photograph of the dissected instrument and a diagram showing mechanical detail were given. The objective was a cemented doublet with the flint component leading. A Porro prism system was used to reverse the field. The magnification was 10, and the definition described as "not good," the illumination being poor. The accuracy of setting for short ranges was of the order of 1 or 2 per cent., provided that the dimensions of the object were accurately known. J. R. C.

32. Previous Forms of Terrestrial Telescopes. M. von Rohr (*Zeitsch. Instrumentenkunde*, 1920, **40**, 15).—A description of a telescope, made by "Berge, London, late Ramsden," about 1811, and used in the Peninsular War by a Prussian fighting in the British Army. The lenses were still in good condition, the objective being a two-piece lens and the ocular consisting of four lenses. The glasses of which the objective was composed were a crown glass, $\mu_D = 1{\cdot}5325$, $\nu = 57{\cdot}8$, corresponding nearly with Schott's zinc-silicate crown O 15, and a flint, $\mu_D = 1{\cdot}5991$, $\nu = 38{\cdot}0$, corresponding with the ordinary light flint 0·318. The crown lens was leading, and the separation between the two lenses was 0·16 mm. The other measurements are also given, the focal length being 500 mm. The lenses of which the ocular was composed were made of a glass with refractive index $\mu_D = 1{\cdot}51$. Both objective and ocular were overcorrected for spherical aberration. The magnification of the telescope was 24·3.

An old Ramsden triple objective is described, the focal length of this being also 500 mm. It was in good condition, though the exterior crown lenses of a similar one had not weathered so well. The flint glass had a refractive index of 1·5961, $\nu = 38{\cdot}3$, being very similar to that used in Berge's objective. The crown glasses were also apparently the same. The performance of the triple objective is better than that of the doublet.

Diagrams of the spherical aberration, and secondary spectra of both objectives and ocular, are given. J. R. C.

33. A New Method of Testing Spectacle Lenses. Solms. (*Die Glashütte*, 1920, **50**, 197).—The method described was one originated by Tscherning. A second telescope, made up with the lens under test as the objective and an ocular of known measurements, was inserted between the collimator and telescope of a spectrometer. The objective of the latter telescope was provided with two marks, the distance between which represented the size of the image before the second telescope was inserted. By means of a micrometer screw, the new image size was ascertained, and this was directly proportional to the focal power of the tested lens. In order to ascertain the radii of curvature of the lens, if the surfaces be concave, a parallel beam of light, provided by the collimator, fell on the lens surface, and was rendered convergent on reflection. The position of the focus, and hence also the radius of curvature of the surface, were ascertained. The method of determining the refractive index of the glass of which the lens is made was the immersion method. Stress was laid on the necessity of maintaining the liquid at constant temperature. The astigmatism of the lens could be studied by placing a diaphragm, 5 mm. in diameter, at the place where the focal point of the eye in relation to the lens would be. The collimator was focussed to give an image and the lens rotated. J. R. C.

34. Chromatic Variation of Spherical Aberration in Cemented Doublets. L. M. GILLMAN (*Trans. Optical Soc.*, 1919, **21**, 53).—The determination of the form of achromatic doublets, designed to give freedom from certain aberrations, had been the subject of numerous investigations, in all of which, with the exception of the work of Steinheil and Voigt, the computation had been algebraical. The results were therefore only approximate, and it was desirable that they should be tested by ray tracing to determine the remaining aberrations. Not only should the objective in question be examined in this way, but also similar objectives differing from it by slight variations in its surfaces. This procedure was adopted in the present investigations. Three series of objectives were examined, namely:—Set I, ordinary silicate crown leading; Set II, flint leading followed by ordinary silicate crown; Set III, medium barium crown leading. The constructional data for these sets were given.

In each series the investigations showed that the results for the intersection lengths of paraxial and marginal rays could be plotted as curves which showed striking uniformity throughout the series. The shape of the curves was very nearly parabolic, and examination of their varying inclinations and curvatures showed that the angle between the paraxial and marginal curves was practically constant, while the curvature of the marginal curve was greater than that of the paraxial curve in a constant ratio. These results led to the conclusion that the curve for any lens in the series could be predicted from a knowledge of both paraxial and marginal curves of one other form. The best results corresponded closely with the objective determined by algebraic calculations, in which thickness was neglected. J. R. C.

35. The Correction of First Order Astigmatism of a Single Lens used with a Stop. T. Y. Baker (*Trans. Optical Soc.*, 1919, **21**, 65).—In a previous paper (Vol. **3**, Abs. No. 164) the range of image positions, for which the correction of first-order spherical aberration was possible, was obtained. In the present paper a similar investigation was made of the positions, for which correction of first-order astigmatism was possible when there was choice of the shape of the lens and of the position of the stop. It was shown that there were two theoretical shapes for a lens, such that, for given image and stop positions, the first-order astigmatism could be made anything desired. There were, however, complications, as these shapes might not be practically possible. A set of constant astigmatism curves was drawn for a glass of refractive index 1·518, and these were so modified that the construction of the lens was practical. These curves should be of use to computers in determining approximately the greatest flattening of field that was possible for a given image and stop positions, and the shape of the lens that would do it. The investigation was extended to a series of lenses along an axis, with special reference to the case of two thin lenses in contact, and made of the same glass. The paper concluded with an investigation into the astigmatism defects of the Ramsden and Huyghens eyepieces.

J. R. C.

36. Glass for Protection from Ultra-violet Rays. (Brit. Pat. No. **118397**, April 15th, 1918, No. 6398.) R. Haddon, London (Corning Glass Works, Corning, New York, U.S.A.)—Relates to the production of glass capable of absorbing ultra-violet rays and as nearly colourless as possible, and consists in adding titanium oxide and an oxidising salt to the glass composition. The titanium compound may be used in conjunction with cerium oxide, etc., and nitre is added to prevent reduction of the oxides.

H. G. C.

VI.—Illumination and Illuminating Ware.

37. The Preparation of Filaments for Electric Incandescent Lamps. (Brit. Pat. No. **120040**.) Westinghouse Lamp Co., Bloomfield, New Jersey, U.S.A. (September 24th, 1918, No. 15523).—Filaments of tungsten, molybdenum, tantalum, or the like are heated in such a way as to acquire a granular structure adapted to restrain structural alterations in use. A texture of medium fineness, containing, say, 12,000—18,000 grains per sq. mm., is found to be most resistant. A coarse structure is obtained by maintaining the filaments for some time at the critical temperature, namely, 1800°, at which grain-formation begins, and a fine structure by heating rapidly to a temperature above the critical point. Successive heating to both temperatures gives a texture of medium fineness. A 40-watt, 110-volt, drawn-wire filament, if heated in the otherwise finished lamp first for five minutes by a current at 80 volts, and then for a like period at 130 volts, acquires a fineness of 12,000 grains per sq. mm. Heating for fifteen minutes by a current of 110 volts gives a fineness of 18,000 grains per sq. mm. H. G. C.

38. The Preparation of Tungsten. O. Bertoya, London (Brit. Pat. No. **119117.**) October 15th, 1917, No. 14915).—Tungsten trioxide is reduced to metal by the action of hydrogen or gas containing more than 50 per cent. of hydrogen while passing through a series of externally heated inclined retorts, down which the material slides. The apparatus shown comprises two sets of retorts, *C*, mounted in combustion chambers, *Z*, to which gas is supplied through nozzles, Z^3, the combustion products passing out through a downtake flue, *L*; or the retorts may be heated by solid fuel, the lowest chamber, *Z*, being then connected through a flue, *J*, with a coke or like furnace. The separate retorts in each set are connected by bends, *D*, having covers, *E*, and with sampling attachments, *Y*, each comprising tubes, Y^1, Y^4, and a plunger, Y^2, which is lowered when required and given half a turn to direct the sample of material into the tube, Y^4. The material is charged and discharged through hoppers, *A*, *M*, each fitted with valves, 1, 2, which may be operated for continuous feed and discharge. The gaseous reducing agent is supplied by valved pipes, I^2, passing through the covers, *E*. H. G. C.

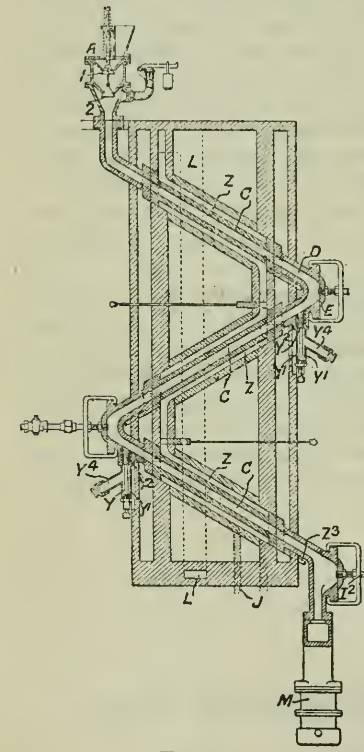

Fig. 4.

39. Vapour Electric Lamps. H. George, Paris (Brit. Pat., March 28th, 1919, No. **7841**. Convention date, August 8th, 1918).—A mercury-vapour lamp contains an inert gas, such as nitrogen, argon, or, preferably, neon, at a pressure of the order of atmospheric. In a quartz lamp, a U-tube, 6, carrying vessels, 7, 8, is fitted to the side of the anode reservoir, 3; the vessel, 8, contains a tube, 11, through which passes a tungsten wire, 12, connected to the positive terminal, and is connected to the lighting tube by a tube, 9, of at least 4 mm. internal diameter. The tube, 10, is provided with a hole, 11, and the vessel, 7, has a constricted neck, 13, of 0·8 mm. diameter. Mercury normally occupies the tube to the level, 14; on making the current, the gas in tube 8 is heated by the wire, 12, and forces the mercury into the vessel, 7, the arc being struck as soon as the mercury column is broken by the bridge of the lighting-tube, 1. The vessel, 8, acts as a condensing chamber, and the passage of vapour through the tube, 9, keeps the lighting tube free from gas. H. G. C.

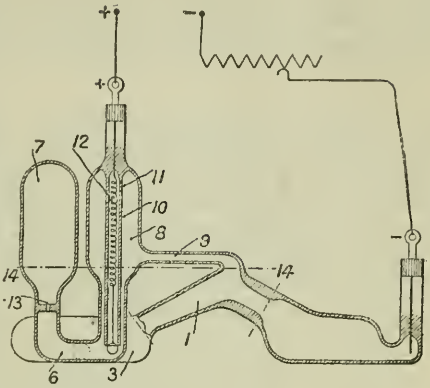

FIG. 5.

VII.—Fuels, Refractories, and Furnaces.

40. Refractory Substances. H. E. MASON and A. COUPER, Horwich, Lancashire. (Brit. Pat. No. **119101.**) (September 27th, 1917, No. 13906).—Relates to the manufacture of refractory magnesite bricks. H. G. C.

41. Alumina for Refractories. NORTON Co., Worcester, Massachusetts, U.S.A. (Brit. Pat. No. **118605.**) (July 11th, 1918, No. 11378. Convention date, August 18th, 1917).—Alumina is prepared in fused condition from crude materials, such as bauxite and clay, by fusing the material with an excess of carbon in an electric furnace, separating the reduction products of the impurities, and then adding a solid oxidising compound to oxidise the partial reduction products of the alumina. As oxidising agents, iron oxide, silica, or titanium oxide may be used, or crude bauxite or volatile materials, such as zinc oxide or sodium carbonate. An excess of the oxidising substance may be employed, with or without some carbon, to reduce a part of the excess. H. G. C.

42. Alumina for Refractories. NORTON Co., Worcester, Massachusetts, U.S.A. (Brit. Pat. No. **118606**.) (July 11th, 1918, No. 11379. Convention date, August 18th, 1917).—A method for preventing the partial reduction of the lower layer of the charge during the electric fusion of alumina. H. G. C.

43. Silica Brick Manufacture. SOC. ANON. DES PRODUITS REFRACTAIRES DE L'OUEST, Paris. (Brit. Pat. No. **118116**.) (August 6th, 1918, No. 12788).—Silica bricks are made from any quartz or quartzite containing an average of 95 per cent. of silica. After disintegrating or after cooling, the material is subjected to a first crushing, and part then reduced to a fine flour by a further crushing. Suitable proportions of the two crushings are mixed together with a binder, such as lime, moulded, and burnt.

H. G. C.

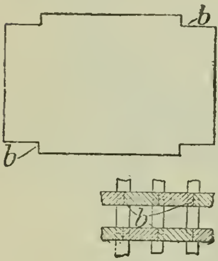

FIG. 6.

44. Regenerator Bricks. T. WILLIAMS (Brit. Pat., August 9th, 1918, No. **12978**).—Chequer bricks are provided with four recesses, *b* (Fig. 6), each approximately equal in length to half the thickness of the brick. The bricks are laid end to end in parallel rows, the bricks in each course running at right angles to those in the courses above and below, so that the recesses, *b*, interlock, as shown in plan view in Fig. 6, to form vertical and longitudinal and transverse horizontal channels. H. G. C.

45. Zirconia. H. E. COLEY (*Chem. News*, 1920, **120**, 7).—The possibility of the use of zirconia as a refractory material on a large scale depended on the cost. Up to the present, no sufficiently cheap process had been devised to allow of the use of pure zirconia in refractory bricks. The problem of plasticity had been largely solved, and the shrinkage could be influenced, as in other refractories, by the addition of grog, and the grog in this case consisted of previously fired and ground zirconia. The firing temperature was governed by the temperature at which the refractory was to be used, and it was essential that the grog should be fired to the same temperature. If vitrified grog were added, it was a source of weakness, and produced a "hackly" fracture, whereas, under proper conditions, a thoroughly plain and homogeneous structure was obtained, the grog uniting completely with the raw material. Fired in a reducing atmosphere, black bricks could be obtained, owing to the capacity of zirconia to absorb carbon, but the colour could be completely removed by firing in an oxidising atmosphere, and there was no evidence of the formation of carbide below the fusion point.

At present, zirconia bricks of suitable shapes could be produced and fired having a melting point of not less than 2300°, a low coefficient of expansion, a low conductivity, a resistance to slags better than that of other refractories, a capacity to resist very great pressures when cold and a greater pressure than other refractories when hot, and could be heated and cooled alternately and rapidly without deterioration. F. W. H.

46. Muffle Furnaces and Kilns. J. H. Marlow (Brit. Pat., May 4th, 1918, No. **7487**).—In a kiln or oven for the manufacture of pottery, tiles, etc., the lining is formed of multitubular slabs, *a*, arranged to provide continuous passages, *c*, extending over the arch of the kiln, each slab being corrugated or fluted on both faces, and being formed to make joint with the slabs above and below, and also to interlock or joint with retaining blocks, *f*, built into the walls of the kiln. The slabs may form a wall between the flues, *h*, for the heating gases and the interior of the kiln, or the passages, *c*, may themselves form the heating flues. In the former case, perforations, *n*, may be provided in the inner faces of the slabs to allow circulation of hot air through the passages, *c*, and the kiln chamber. The joint with the blocks, *f*, is formed by a rib, *d*, and groove, *c*, and recesses, *m*, are provided in the upper and lower edges of the slabs to receive strips, *l*, of fireclay binding. Instead of interlocking at the sides with the blocks, *f*, the slabs may interlock with one another, as shown in Fig. 7. The foundation blocks may be recessed to the contour of the slabs. H. G. C.

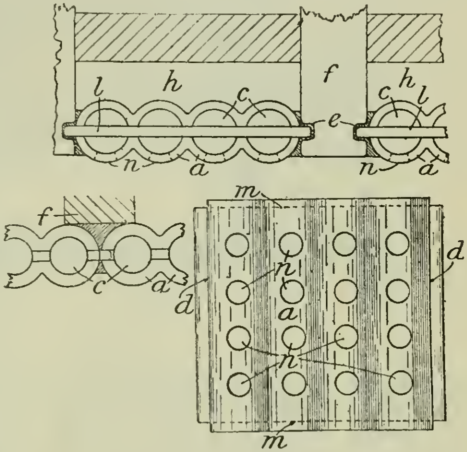

Fig. 7.

47. Tank Furnace for Drawing Sheet Glass. Henry Douchamp (U.S.A. Pat., March 25th, 1919, No. **1298474**. Filed September 20th, 1916. No. 121222).—The specification describes a tank furnace construction forming part of an apparatus by which cylinders of sheet glass are drawn directly from the metal in the tank. The furnace is provided with a number of drawing stations, 6 (Fig. 8), each consisting of a forehearth or doghouse projecting into the body of the tank, and formed by vertical blocks, 13, of refractory material suspended from girders, 27. The lower part of the blocks, 13, co-operates with front blocks, 9, to form a platform, which is pierced with a circular drawing opening, 7. The suspending rods, 23, of the blocks, 13, are screwed, and can be adjusted vertically by means of nuts, 25, the frame, 24, carrying the rods being also adjustable vertically. Thus individual blocks may be adjusted, and the whole of the blocks may be moved to alter the level of the drawing opening, 7. Adjacent to each forehearth, two or more rings, 33, of refractory material, attached to a spider, 34, float on the surface of the metal in the tank, and the stem, 37, of the spider is connected to a shaft, 40, which can be rotated. In use, after a cylinder is drawn and detached, the shaft, 40, is rotated to bring a fresh ring, and therefore a freshly heated body of metal, beneath the opening, 7, while the ring just used, with the chilled glass attached, is turned into the body of the tank to be re-heated. G. D.

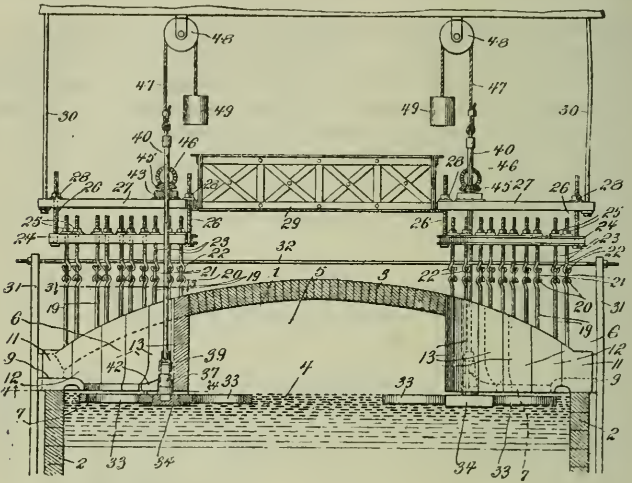

FIG. 8.

48. Wire-wound Electric Furnaces. J. A. FLEMING (Brit. Pat., April 9th, 1918, No. **6039**).—A heating wire is hung in free loops from supports on the furnace wall, which has high heat-insulating power. The wire, *r*, may be of nichrome of uniform section and resistance, and without joints. It is slightly spaced from the wall. Short-circuiting may be prevented by distance-pieces of fused quartz, alundum, or diatomaceous brick. The loops may be supported by iron or copper lugs or strips, or by notched projecting bricks, *k*. They may be arranged in series or parallel, or for polyphase currents. The wall may be of fire-

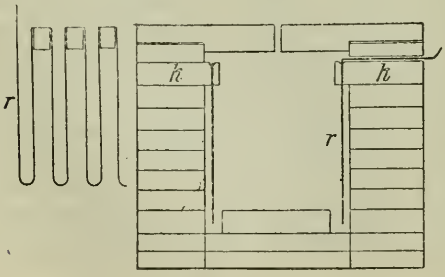

FIG. 9.

clay, silica, or diatomaceous bricks, surrounded by slag wool in a brick or iron cylinder, or a very thick wall of diatomaceous brick may be surrounded by stock or fire-bricks. A door or lid is made of asbestos or diatomaceous brick, with an aperture for inspection and for a pyrometer. Current may be regulated by a choking coil with an adjustable core. The furnace is suitable for annealing iron or steel, or heating it to a welding temperature, or for melting other metals. Dimensions are given. H. G. C.

49. Electric Induction Furnaces. Ajax Metal Co., Philadelphia, Pa., U.S.A. (Brit. Pat. No. **119220**.) (March 19th, 1918, No. 4868).—Induction heating is effected by the use of high-frequency currents, obtained by condenser discharge, or impressed by a high-frequency generator on an approximately tuned circuit containing the inducing coil. Frequencies of 12,600 and 25,400 have been found suitable. The power factor may be unity. No iron core is required in the heater. Fig. 10 shows an inducing coil, O, connected to supply conductors, A, A^1, through a condenser, C, in one lead, and inductances, L^1—L^4, in both leads. A spark-gap, G, shunts the leads between the two pairs of inductances. Alternatively, the inducing coil may be arranged in the shunt circuit containing the discharge-gap. Instead of the inductances, L^3, L^4, a blow-out device may be provided for preventing short-circuiting by the discharge. A step-up transformer is added if the supply pressure is too low, the two inductances, L^3, L^4, being in either the primary or secondary circuits. Fig. 10 shows two-phase transformers, D, D^1, with condensers, C, C^1, in the outer conductors of the secondary circuit and discharge-gaps, G, G^1, and inducing coils, O, O^1, connecting the outer and

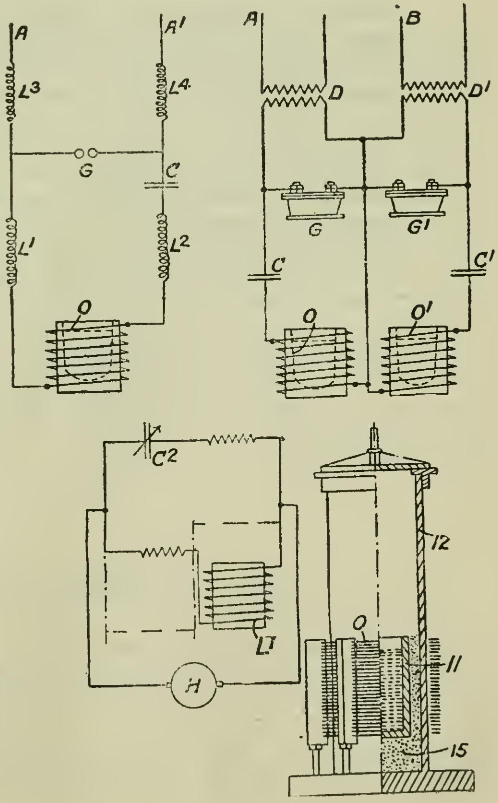

Fig. 10.

common conductors. A single inducing coil in the common conductor may, less advantageously, replace the two coils shown. Both inducing coils may surround one crucible. Variable inductances may be placed in the primary circuits, *A*, *B*, for current regulation. When a high-frequency dynamo, *H* (Fig. 10), is employed, it may be connected, directly or through a transformer, to a variable condenser, C^2, shunting and inducing coil, L^7. A current much larger than that traversing the generator can then be produced in the circuit of the condenser and coil. A discharge-gap may be added to this arrangement. In a vacuum furnace, a crucible, 11 (Fig. 10), may be supported by non-conducting material, 15, in an exhausted casing, 12, surrounded by the inducing coil, *O*. Either the crucible or the charge may act as the secondary circuit. In the latter case, electro-dynamic circulation is produced. The invention is applicable to the heating of metal billets or blooms to be worked, of thin metal shells, and of liquid or pasty substances. Solid bodies may be heated locally.

H. G. C.

50. Furnace Temperature Regulator. W. P. WHITE and L. H. ADAMS (*Phys. Review*, 1919, **14**, 44).—The authors described an arrangement whereby they were able to maintain the temperature of a small electric furnace constant at 0·1° for hours at various temperatures from 500° to 1400°. The heating coil of the furnace was arranged as an arm of a Wheatstone bridge, and by combining it with a galvanometer regulator, the coil resistance was kept constant, and hence also the furnace temperature. Any change in the furnace temperature with the corresponding change in the resistance of the heating coil caused a boom to connect or disconnect a contact breaker. This contact breaker controlled a relay, which in turn operated a magnet, which controlled the main current supply.

The advantages of this method of control were that it was independent of variations in the supply current; nothing had to be placed in the interior of the furnace; there was practically no lag; the power available in the regulator was very large, and it required little or no attention.

F. W. H.

VIII.—Chemical Analysis.

51. The Indirect Detection of Tin. F. FEIGL (*Chem. Zeit.*, 1919, **43**, 861).—In the method described, the mixed sulphides of antimony and tin were dissolved in hydrochloric acid, and the solution divided into two portions. One portion was tested for antimony with an iron wire. By means of pure zinc, the two metals were precipitated from the second portion, and the tin dissolved out in concentrated hydrochloric acid. This solution was poured into a hot dilute solution of ferric chloride. Then a small quantity of citric acid or sodium potassium tartrate was added, followed by an ammoniacal solution of dimethylglyoxime in alcohol. A red coloration was obtained, the intensity of which varied with the quantity of stannous chloride present. The precipitation of iron was prevented by the addition of the citric acid or sodium potassium tartrate, but the presence of ferrous iron, produced by reduction of the ferric chloride by the stannous chloride, was indicated by the production of the red coloration. F. W. H.

52. Separations in the Arsenic Group. W. Strecker and A. Riedemann (*Ber.*, 1919, **52**, [*B*], 1935).—The usual distillation method for the estimation of arsenic was modified by the addition of thionyl chloride or phosphorus trichloride. The flask containing the arsenic, concentrated hydrochloric acid, and 1·5 grams of potassium bromide was heated until the contents boiled, and then 10 c.c. of thionyl chloride were run in gradually through a tap funnel, the transference taking thirty minutes. The distillate was diluted to between 700 c.c. and 800 c.c., and then boiled under a reflux condenser, a current of carbon dioxide being passed through the flask to assist in the expulsion of the sulphur dioxide. The boiling was continued until the precipitated sulphur collected, and then the distillate was filtered and the arsenic estimated in the filtrate as trisulphide.

Instead of thionyl chloride, 25 c.c. of phosphorus trichloride might be used, in which case the boiling of the distillate was unnecessary, but the presence of phosphorus acid in the residue possibly introduced complications in subsequent estimations.

By this method. arsenic was accurately separated from copper, lead, mercury, antimony, tin, and also from iron. Antimony was separated from tin by rendering the tin non-volatile by the addition of phosphoric acid, whilst antimony chloride was volatile at 155—165°. When the antimony was removed, hydrobromic acid was added to the residue, the temperature slightly increased, and the tin volatilised.

Antimony and copper in hydrochloric acid solution were separated by adding this solution to a mixture of 6 c.c. of concentrated sulphuric acid and 7 c.c. of phosphoric acid (specific gravity 1·78) and distilling, the distillate being received in hydrochloric acid in this case instead of water. The distillation was carried out at a temperature of 160°, and during the operation a mixture of ten volumes of concentrated hydrochloric acid and one volume of hydrobromic acid (specific gravity 1·78) was run into the distillation flask, the rate being such that the temperature of distillation remained constant. Complete volatilisation of the antimony occurred in thirty minutes, and similarly in the case of a mixture of antimony and lead.

Tin was separated from copper and lead in a very similar manner, 12 c.c. of sulphuric acid being used, and 20 c.c. of the mixture of hydrochloric and hydrobromic acids. The tin, completely volatilised in thirty minutes, was precipitated from the distillate as sulphide and estimated as oxide. Neither antimony nor tin could be separated in this manner from mercury, since the mercury was also volatilised. F. W. H.

53. Colorimetric Determination of Small Quantities of Uranium. E. MULLER (*Chem. Zeit.*, 1919, **43**, 739).—The author described a method in which the dilute solution of the uranium salt containing about 0·02 per cent. of uranium was treated with sodium salicylate solution, and the red coloration so obtained compared with that given by a known amount of uranium treated in similar fashion. Iron salts, alcohol, and acetone interfered with the estimation, and free mineral acids and acetic acid should be absent. Free mineral acid being present, sodium acetate should be added, and the free acetic acid removed by evaporation. Neutral alkali salts had no effect on the reaction. F. W. H.

IX.—Machinery for the Working of Glass.

54. Bottle Blowing Machinery. S. D. OLSEN (Brit. Pat., June 17th, 1918, No. **9981**).—A rotary machine in which the parison moulds are mounted on an upper, and the finishing moulds on a lower, table is provided with turnover mechanism, by which the parison is automatically transferred from one mould to the other. The rotary tables, a, a^1, are carried on a sleeve turning on a pillar, B, and intermittently driven by a cam groove on a roller, A^2, engaging studs, A^4. The parison moulds, b, and the finishing moulds, b^1, disposed as shown, open and close in the usual manner. The neck mould, i^3, is divided, and its halves are loosely connected to spring-pressed levers, i^2, carried by a bracket, i, pivoted on an horizontal axis, i^1, and capable of being revolved through 180 degrees by spur gearing, i^6, i^7. A shaft, c, within the pillar, B, is raised and lowered, during the movement of the tables, through a double lever, l^1, k^3, on a rocking shaft, l, by a cam, e, on the roller, A^2, and carries at its upper end four arms, of which three, f, f^2, f^3, are shown in Fig. 11. The arm, f, carries a spring-mounted cover, g, for closing the parison moulds, the arm, f^2, carries a blowing head, h (Fig. 11), and the remaining arms carry spring-mounted brackets, f^6, which engage arms, i^8, on the bracket, i, and effect the turnover action. A blowing-plug, k, mounted on a slide, k^2, actuated from the shaft, c, is adapted to supply air to blow the parison in the parison mould. The operation of the machine takes place in six stages. (1) The parison mould is closed for charging by a plate carried by a lever on the shaft, l, and is charged with molten metal. (2) The cap, g, is brought down on the parison mould, the plug, k, is inserted into the neck-ring, and the preliminary blowing is effected. (3) The parison mould, having been opened, the neck-ring carrying the parison is turned over by the bracket, f^6, actuating the arm, i^8, and thus the gearing, i^6, i^7. (4) The finishing mould is closed on the parison, the blow-cap, h, lowered on the mould, and the bottle blown. (5) The blow mould opens, and projections on it engage and open the neck-ring, thus freeing the bottle. (6) The neck-ring is turned back to its initial position ready for the parison mould to close upon it. The levers, l^1, k^3, are connected by a spring connection, k^4, and similar spring devices are fitted to the lever, d^1, and the lever carrying the plate for closing the parison mould.

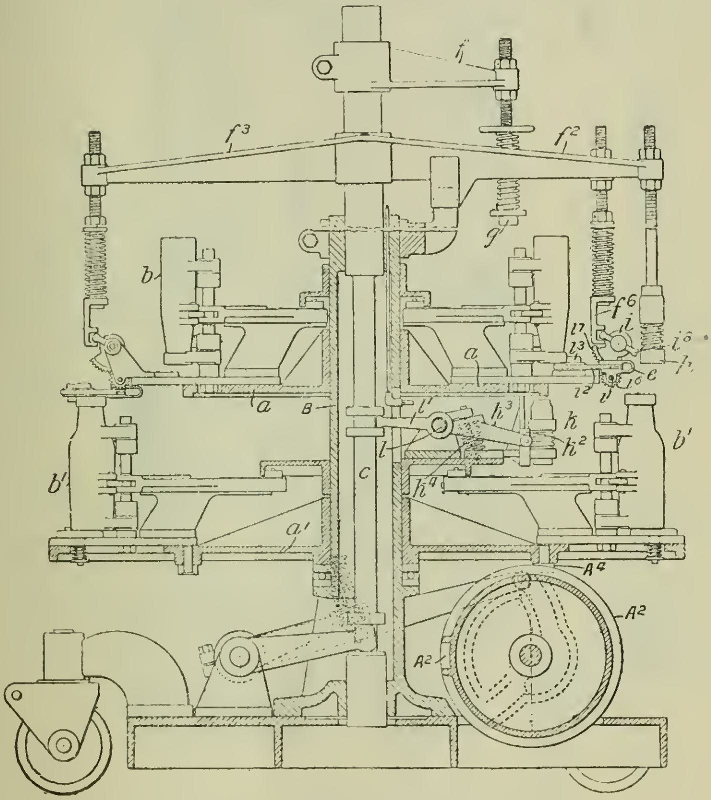

FIG. 11.

H. G. C.

55. An Automatic, Self-feeding, Bottle-making Machine. T. Stenhouse (U.S.A. Pat., March 18th, 1919, No. **1297412**. Filed November 12th, 1914. No. 871659).—The invention consists of an automatic press-and-blow machine, particularly intended for making bottles with externally screwed necks, and comprises a flow-feed device. The table, *D* (Fig. 12), that carries the moulds is rotated step by step about a central column, 20, by means of a helix cam, 13, which engages rollers, 14, projecting from the underside of the table. The rollers, 14, are also engaged by spring cams, which assist in starting and stopping the table without shock. A shaft, 22, journalled in bearings in the column, 20, and driven

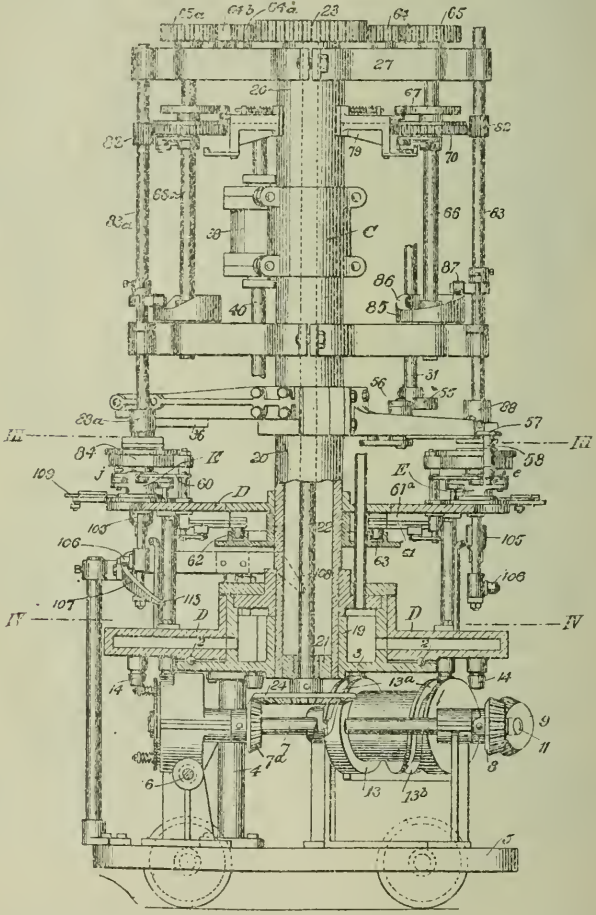

Fig. 12.

from the motor shaft, has a "master gear," 23, secured to its upper end, through which it drives the various mechanisms for pressing, blowing, etc.

The means for feeding the metal in regulated charges to the machine consists of a container, 37, shown in plan in Fig. 13, through which a stream of metal flows into the parison moulds from a spout projecting from the tank. The stream of metal is intermittently severed and supported by a water-cooled knife, 36, pivoted to the frame of the container, 37, and oscillated by a sliding bar, 33. A cam, 32, secured on a shaft, 30, engages a latch, 34, thus moving the bar and swinging the knife from under the container. When the cam releases the latch, 34, a spring, 35, returns the knife and interrupts the flow. The movement of the table carries the mould containing the charge of metal to station, *b*, where the charge is pressed into a parison by means of a plunger, 39 (Fig. 14), operated by an air cylinder, 38. The movement of the piston in the cylinder is controlled by two valves, 46, 47, which are alternately opened, to admit air to the cylinder, by means of a rocking-bar, 43, operated by a cam, 42, on the shaft, 32. A sleeve, 48, which may be moved along the bar, 43, by a

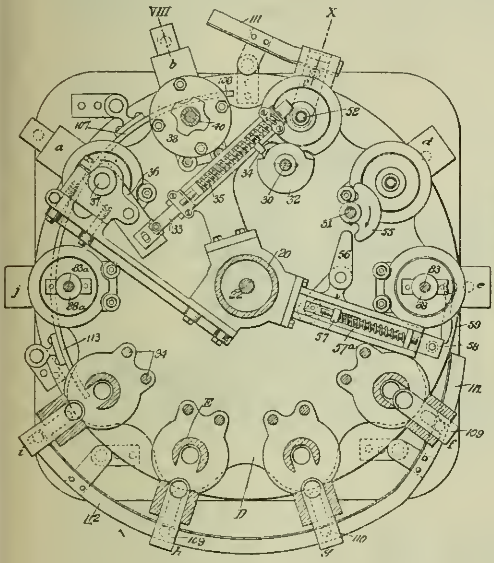

FIG. 13.

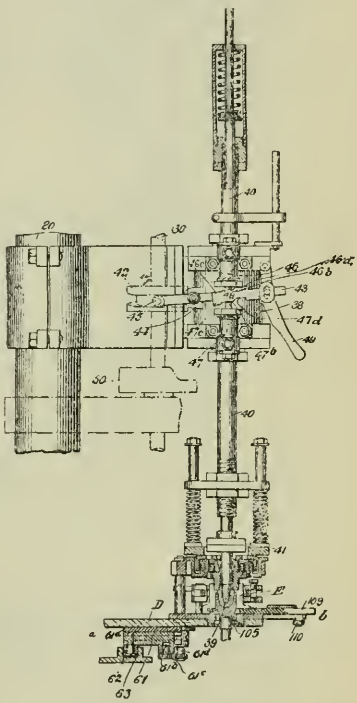

FIG. 14.

handle, 49, enables the operator so to control the valves that the plunger can be maintained either in its raised or in its lowered position.

As the table moves to carry the parison to the next station, the parison mould, 105, is lowered beneath the table, *D*, thus leaving the parison suspended from the ring mould within the blow mould, *E*. At the same time, the bottom, 109, of the blow mould is moved inwards by the engagement of its roller, 110, with a cam, 111 (Fig. 13). The parison is then blown by means of a blowhead, which is raised from, and lowered on to, the ring mould by a cam on a rotating shaft. The blowhead consists of a valve, 53 (Fig. 15). free to slide on the lower end of the air tube, 52. When the valve makes contact with the ring mould, further movement of the tube, 52, lifts an inner valve, 54, off its seating and releases the air. The mould is moved to the next station, where the ring mould is screwed off the neck of the bottle by mechanism shown in Fig. 16. The ring mould, 100, is carried by a support, 99, which screws into an annular member, 96, rigidly supported above the blow mould. A shaft, 83, has a collar, 91, on its lower end which has projecting pins, 92, that can engage apertures, 104, in the upper surface of the member, 96. In operation, the shaft, 83, is lowered so that the pins, 92, enter the apertures, 104, and is then rotated. The support, 99, is thus turned and screws the ring mould off the neck of the bottle. At the next stations, the mould is unlocked and opened, and the bottle is presented for removal. Finally, the mould is locked again and the ring mould screwed down by mechanism similar to the screw-off device.

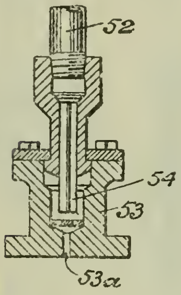

FIG. 15.

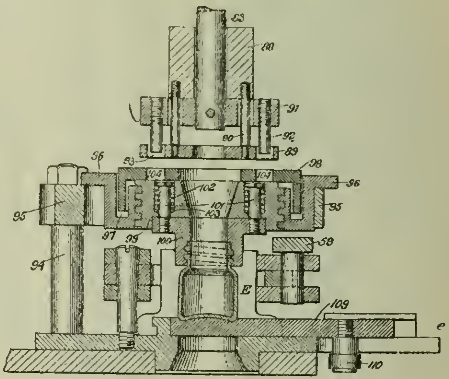

FIG. 16.

G. D.

56. Glass Pressing Machines. W. J. MILLER U.S.A., (Brit. Pat., August 8th, 1918, No. **19289/19**).—Relates to a press for moulding glass articles. The plunger, *P* (Fig. 17), is mounted on a movable cross-head, *N*, connected with a fixed cross-head, 126, by toggles, 174, 176, which are operated through links, 175, by a cross-head, 172, moved up and down by fluid pressure acting in the cylinder, *J*. The capacity of the cylinder, *J*, can be varied by moving a false head or piston, 133 (Fig. 17), which is fixed to a screwed sleeve, 132, passing through the true cylinder head, 130. An extension, 134, of the piston-rod, 129, is grooved at 136 to allow fluid pressure to pass from the supply pipe, 152, through the sleeve, 132, into the space between the false head, 133, and the piston, 128, and so cause this to descend. The piston is raised by air admitted through a pipe, 149. The last part of the upward movement of the piston, 128, closes the entrance to the groove, 136, and the imprisoned air is allowed to escape slowly through a small port, 140, thus producing a cushioning effect. The height of the cylinder, *J*, and of the cross-head, 126, attached to it, is adjusted by screw collars, 146, 148.

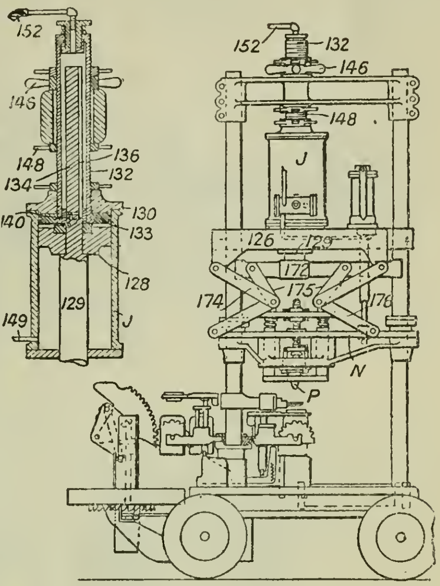

FIG. 17.

Further devices by the same inventor are as follows:—(Brit. Pat., August 8th, 1918, No. **19290/19.**)—This relates to apparatus for discharging the finished glassware from the moulds of a press. The moulds, *E*, are carried on trunnions, 20, on a frame, *D*, which is rotated step by step by a fluid-pressure cylinder, 37. The gatherer places the charge in the mould and presses the punty upon a valve, which starts the machine, after which the cycle of operations is completed automatically by fluid-pressure mechanism. Shears cut the depending charge from the punty, and the charged mould is carried round to the pressing station, where the plunger descends and compresses the charge. The further rotation of the frame, *D*, causes a rod, 27, to strike a cam, 36, and so raise the mould top, 34, which it supports. A toothed arc, 21, on the mould, *E*, engages another toothed arc, *H*, which is swung downwards by a fluid-pressure cylinder, etc., 95, and so inverts the mould and discharges the finished article into an annular trough, 87, containing sand, etc., to cushion the fall.

The tappets of the slide valve controlling the fluid-pressure supply to cylinder 95 are operated by a block fixed to the piston-rod, 38, of cylinder 37. The annular trough, 87, is rotated intermittingly in unison with the frame, *D*, so that successive articles do not fall upon one another. The trunnions, 20, are off-set, so that the mould, *E*, turns back to its normal position by its own weight when disengaged from the arc, *H*, and a stop, 22, keeps it upright.

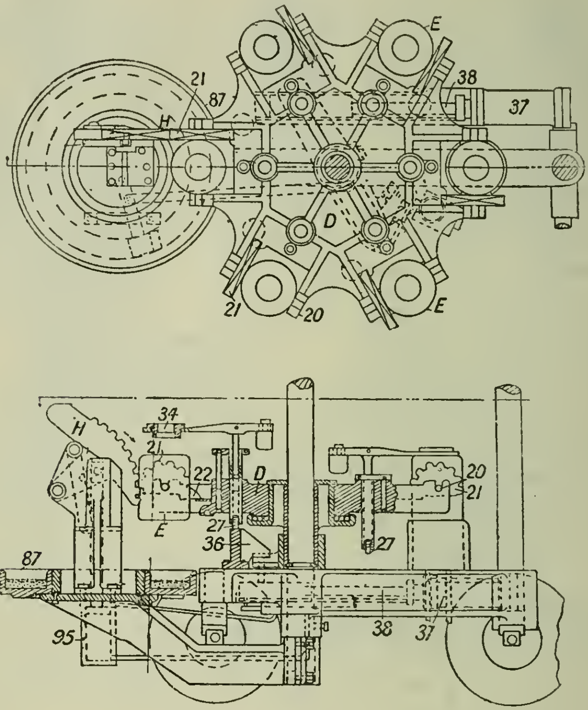

FIG. 18.

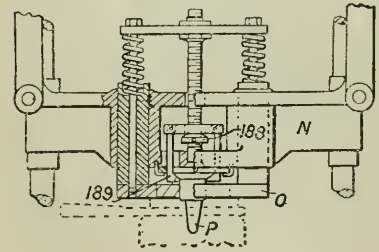

FIG. 19.

(Brit Pat., August 8th, 1918, No. **19291/19.**)—In a machine for moulding glass articles, the plunger, *P*, is centred above the mould and then clamped to the cross-head, *N*, by hooks, 189, which are drawn upwards by a nut, 188. The hooks, 189, are also moved radially by a cam ring. The plunger, *P*, passes through a spring-pressed plate, *O*, which rests upon the top of the mould during the pressing operation.

(Brit Pat., August 8th, 1918, No. **19292/19.**)—In a press of the type in which the moulds, *E*, are carried on rotating arms, 16, a cylindrical block, 113, is mounted directly below the pressing plunger and is surrounded by a sleeve, 114, having a bevelled upper edge, *T*, and is thus raised slightly, being supported during the pressing operation by the block, 113, the arms, 16, thus being relieved of strain. The sleeve, 114, is raised to the position shown by fluid pressure acting on a piston, 119, as soon as the mould, *E*, is in position above the block, 113. Accurate centring is thus insured.

H. G. C.

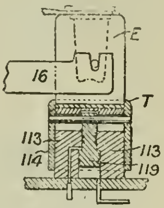

Fig. 20.

57. Glass Pressing Machine. W. A. Lorenz (U.S.A. Pat., January 21st, 1919, No. **1291952**. Filed December 26th, 1913. No. 808803).—The specification describes a rotary power-driven press, evidently intended for use with an automatic feeding device. The machine consists of a number of plungers and associated moulds which rotate about a central vertical column, and the construction shown in the drawings appears to be arranged for producing tumblers of the kind used for containing potted foodstuffs. The table, 3 (Fig. 21), of the machine rotates on ball bearings, 4, about the central column, 2, and has gear teeth, 5, formed on its edge, by which it is driven. A turret, 16, mounted on the table, forms with the table a support for the pressing devices, and within the turret a cylindrical casting, 17, secured to the column, 2, has cam grooves formed on its surface, by which the pressing devices, etc., are operated. The pressing plungers, 50, are carried by yokes, 31, which slide on vertical guide rods, 30, arranged in pairs at intervals around the table. Each plunger is raised and lowered by a toggle joint consisting of a connecting rod, 32, which is pivoted to the plunger yoke, 31, and to a crank arm, 33. The boss of the crank is formed with gear teeth, 42, which mesh with a rack, 43, that slides vertically, and is provided at its lower end with a roller, 45, which engages in a cam groove formed on the cylindrical casting, 17. Thus, as the table, 3, rotates, the plunger is caused to rise and fall. The arrangement of the moulds is a feature of the invention. They are mounted in pairs, 20, 21, on a **Z**-shaped carrier, 22, which turns on trunnions, 24, so that each mould turns over, to discharge the finished ware, about an axis that is tangential to the circle of rotation of the table. Rotation of the moulds is effected at the proper times by gearing operated by a cam roll that engages a groove, 74, in the casting, 17. In order to support the moulds during pressing, a movable abutment, 78, slides beneath the mould, and is removed when the mould is ready to rotate to discharge the finished article. The abutments, 78, are operated by springs, 82, and by cam rolls, 79, which engage a cam surface, 80, on the casting, 17. The mould rings, 90, are carried by yokes, 91, that slide on the vertical guide rods, 30, and are operated by rods, 96, having cam rolls, 94, which engage in a cam, 93, on the base of the machine. After the pressing operation, the mould carrier is turned over to bring a new mould into position. The finished article is not discharged immediately, however, but is retained in the mould while setting by fingers, 111, pivoted to the mould carrier. These swing out of the way at the proper time, and the discharge of the article from the mould is ensured by small hammers, 130, which strike the movable bottom of the mould. G. D.

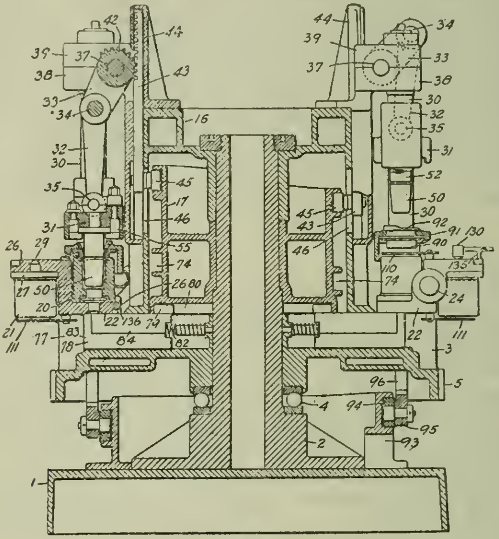

FIG. ~~12~~. 21

58. Machinery for Moulding Glass. W. J. MILLER, Swissvale, Pennsylvania, U.S.A. (Brit. Pat. No. **118282.**) (August 8th, 1918, No. 12883).—Relates to a rotary-table moulding machine actuated by fluid pressure. A series of moulds, *E*, are suspended on trunnions at the ends of radial arms on the table, *D*, connected to a boss turning on a pillar, *C*, and driven intermittingly by an oscillating arm actuated by a piston in a cylinder, 37. An automatically actuated pin engaging holes in the underside of the table serves to lock the table in successive positions. The glass is fed into a mould when in the position shown at the right of Fig. 22, and the workman then actuates a valve by means of his punty, causing shears, 83, to be pneumatically operated to sever the charge. The table then moves automatically, and the cover, 34, is brought down upon the mould, which rides up on a block, *I*, when it reaches the moulding station. The block consists of an inner fixed part and an outer sleeve, which is forced upwards by pneumatic pressure to support the mould. The die, *P* (Fig. 22), is adjustably mounted on a sliding frame, *N*, which is connected by adjustable toggle levers, 175, with a cross-head, 172, carried by the rod, 129, of a piston working in a vertical cylinder, *J*, supported by the pillars, *B*, *C*. The cylinder is fitted with an adjustable false end to regulate the movement of the piston, and air is first admitted slowly to give a slow initial movement, and then more rapidly, the final pressing being effected by the toggle levers. The time during which the die remains in the glass is determined by timing mechanism, *M*, of the kind described in the U.S. Specification 941935. After the moulding has been completed, the table moves forward, and when it reaches the discharging position the mould is turned over by a toothed segment, *H*, engaging a segment, 21, and the finished article is delivered into an annular rotating sand-box. The cylinder, *J*, is supported by a screwed stem, 132, which can be adjusted vertically for moulding articles of different lengths. It is stated that the apparatus is applicable to blowing machines.

H. G. C.

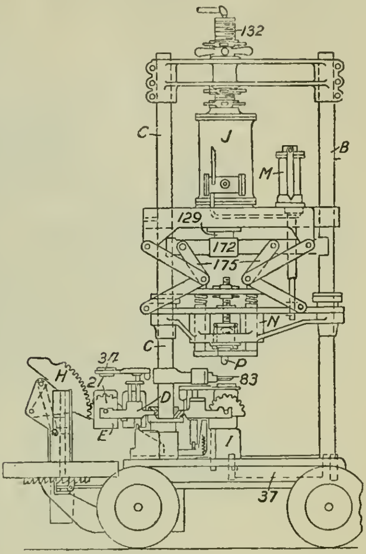

FIG. 22.

59. Timing Devices for Glass Pressing Machinery. HARTFORD-FAIRMONT Co., U.S.A. (Brit. Pat., July 28th, 1919, No. **18714**).—Relates to machines for moulding plastic substances, such as glass, and particularly to the mechanism for timing the movements of the plungers and tables of the rotating table type of machine, such as is described in Specification 120907*. The invention is stated to be applicable also to glass-blowing machines. The table, 23, is rotated intermittently by the engagement of a roller, 32, on a crank, 31, with passages, 28, between blocks, 27, on the under surface of the table, 23. A cam-shaft, 46 (Fig. 29), is driven by bevel-gear, 49, 50, from the crank-shaft, 30, and carries a cam, 45, which draws the crank, 31, down clear of the blocks, 27, against the action of a spring, by means of levers, 41, 43, on a rocking shaft, 42. A spring bolt, 54 (Figs. 26 and 27), engages holes, 53, in the table, 23, to hold it at each station, and is drawn down free of the table by a cam, 62, on the rocking shaft, 42, and rocking levers, 56, 61. If the bolt, 54, is not in one of the holes, 53 (Fig. 27), a detent, 68, connected with the lever, 56, engages a lever, 69, on the rocking shaft, 42, and prevents the crank, 31, from rising and striking the blocks, 27. Normally, the

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Fig. 23.

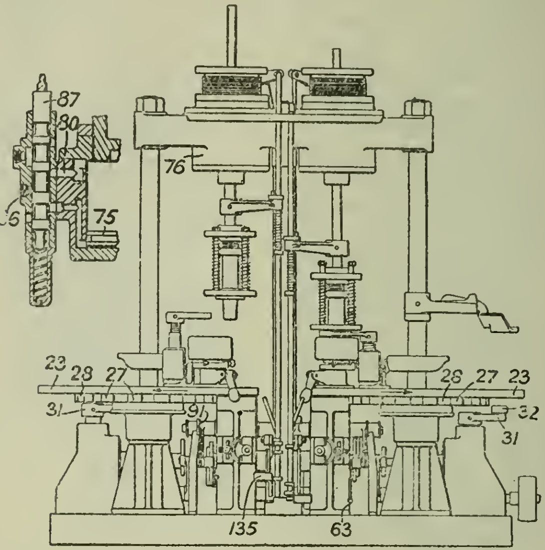


Fig. 24.

Fig. 25.

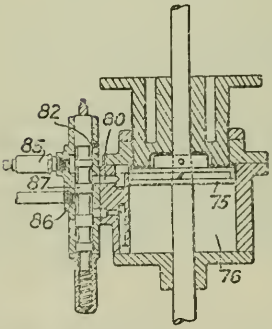


Fig. 26.

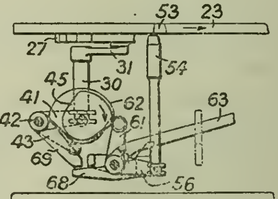
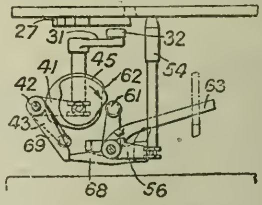


Fig. 27.



crank, 31, is allowed to rise (Fig. 26), and the bolt, 54, is then lowered to free the table, 23. The crank, 31, is also automatically held down in the event of the pressing plunger failing to rise. The piston valve, 87 (Fig. 24), which controls the fluid pressure operating the piston, 75, of the pressing plunger, is operated by a cam, 97, on the shaft, 46. The cam, 97, consists of the segments 100, 101, 104 (Figs. 28 and 29), which can be adjusted relatively to one another, while the machine is running, to alter the valve timing. In its upper position, Fig. 24, the valve, 87, admits pressure above the piston, 75, by way of the passages, 86, 80, to press the ware. As the valve, 87, descends it cuts off the passage, 80, from the pressure inlet, 86, and places it in communication with a relief valve, 85 (Fig. 25), which allows some of the pressure to escape from the cylinder, 76, and so reduces the pressure on the glass, etc., in the mould. The further descent of the valve, 87 (Fig. 25), admits pressure below the piston, 75, and exhausts it from above through a port, 82. The locking-bolt, 54, can be held down by a hand-lever, 63, and the valve, 87, can be raised, and hence also the pressing-plunger, by a hand-lever, 91. The crank, 31, can be held down by a treadle, 135 (Fig. 29).

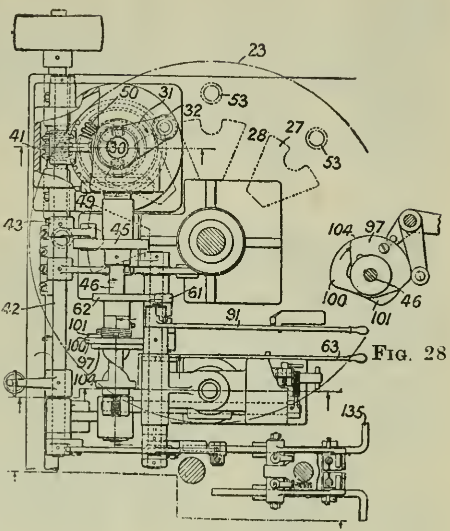


FIG. 28

FIG. 29.

H. G. C.

60. Feeding Glass-making Machines. R. E. McCauley, London. (Brit. Pat. No. **118585**.) (May 31st, 1918, No. 9030).—Relates to means for conveying molten metal from the melting tank to machines, and consists of an arrangement by which separate machines may be supplied in succession. In the arrangement shown, shoots, *c*, *c′*, mounted on pivots, are actuated by compressed-air cylinders, *e*, so that they are alternately brought under the outlet, *d′*, of the melting tank, *d*.

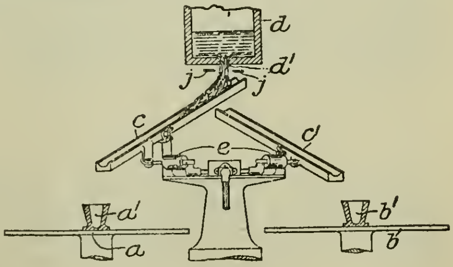


FIG. 30.

The shoots respectively deliver the charge to the moulds, *a′*, *b′*, on the rotary tables, *a*, *b*. In another arrangement, one of the shoots is stationary and the other is moved so as to intercept the discharged glass at intervals. The shoots may have a sliding instead of a swinging movement, and may be driven by any suitable mechanism. To prevent overheating, the shoots are formed hollow, and cooling fluid is circulated through them. The metal is severed by the usual shears, *j*. H. G. C.

61. Glass-tumbler Press. Karl E. Peiler (U.S.A. Pat., January 21st, 1919, No. **1292033**. Filed August 11th, 1913, No. 784194).—The invention consists of a tumbler-pressing machine that is a more elaborate form of the machine which forms the subject of U.S.A. Pat. 1291952 (see abstract No. 57). In the present invention, the rack, 34, that raises and lowers the plunger, 121, only actuates the plunger during its free, or non-pressing, movements, the cam groove, 123, 124, which operates the roller, 125, of the rack being open, as shown, when the plunger is in position to press the glass. The pressure for shaping the metal in the mould, 40, is obtained from a pressing-lever, 36, which rocks on the shaft, 33, and has at its outer end a pawl, 37. This pawl engages a shoulder on the crank, 128, when the plunger is in the pressing position, and thus tends to straighten the toggle joint. The inner ends of the levers, 36, engage in slots in a collar surrounding the central column of the machine. A shaft, which reciprocates within the central column, carries an electromagnet that picks up the collar, and thus rocks the levers, 36. A pivoted guard, shown in dotted lines, is moved forward by a cam, 181, carried by the next preceding plunger mechanism, and prevents the pawl, 37, from engaging the shoulder of the crank until the plunger is lowered into the mould. G. D.

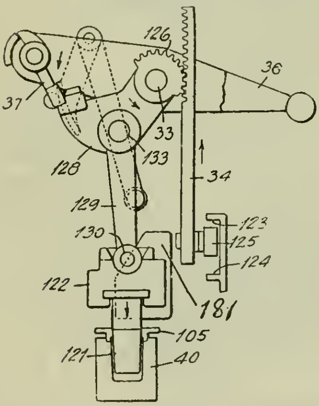


Fig. 31.

62. Device for Promoting Uniformity of Flow in Glass Feeder. R. E. McCauley, London. (Brit. Pat. No. **118581.**) (May 21st, 1918, No. 8472).—Delivering molten metal. Relates to arrangements in connection with glass-melting tanks to secure that the metal delivered is of uniform character by preventing its being unequally chilled at the cooler end of the tank. In the arrangement shown in Fig. 32, the tank is fitted with a transverse dam, 11, formed in one with an horizontal part, 11^a, which rests on the top of a cylinder, 12, forming the conduit to the outlet, 8^a. The arrangement causes the metal to pass round the cylinder, 12, and then upwards at the wall, 9, of the tank, as shown by the arrows. The invention is shown as applied to apparatus of the type described in Specification 113665, in which the discharge is pneumatically controlled through a cylinder, 10. In a modification, the dam is formed as an open cylinder with the opening towards the wall, 9, and extends to the bottom of the tank. H. G. C.

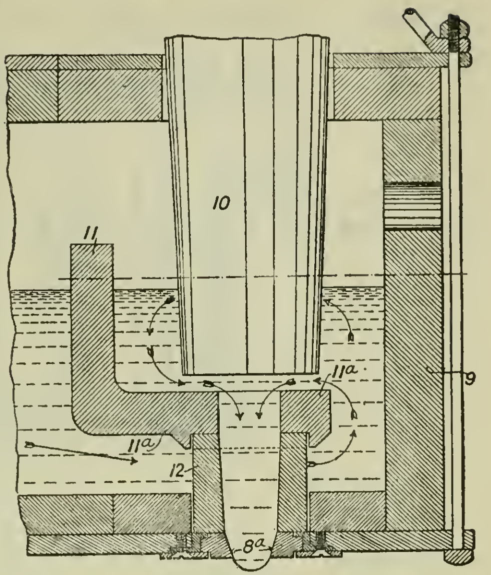


Fig. 32.

63. Apparatus for Drawing Glass Cylinders. William Westbury (U.S.A. Pat., February 18th, 1919, No. **1294581**. Filed June 26th, 1917, No. 176955).—Relates to apparatus for drawing glass cylinders, in which a tank furnace is provided with one or more forehearths or doghouses from which the metal is drawn. Such a doghouse, as shown in Fig. 33, consists of a horizontal top wall, 6, resting on a front wall, 3, and having a drawing opening, 9, and a wall, 7, filling the space between the topstone, 6, and the furnace crown, 1. According to the present invention, the vertical wall, 7, is made up of a series of vertical blocks, 10, which are tongued and grooved on their meeting faces, and the topstone, 6, is also composed of a series of blocks, 13, fitted together. Thus the walls can be repaired by the replacement of one or more damaged blocks. The topstone, 6, is supported by rods, 20, depending from the usual trussing, 23, and screwed at their lower ends into an iron pipe, 18, which passes through channels, 17, in the blocks, 13. The rods, 20, are housed in recesses, 21, in the blocks, 10, in order to protect them from temperature variations.

The pipe, 18, may also be used for the circulation of a cooling

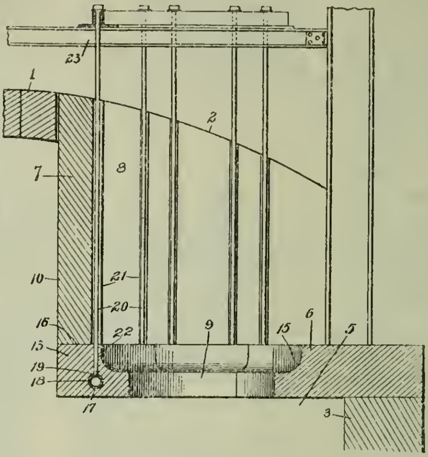


Fig. 33.

fluid, such as water, air, or steam. U.S.A. Pat. No. 1187025 is referred to in the specification. G. D.

64. Drawing Glass Cylinders. William E. Standley (U.S.A. Pat., June 24th, 1919, No. **1307381.** Filed November 17th, 1915, No. 61974).—A blowhead used in drawing cylinders is provided with means for regulating the pressure of air within the cylinder in order to avoid the defects produced by air pulsations.

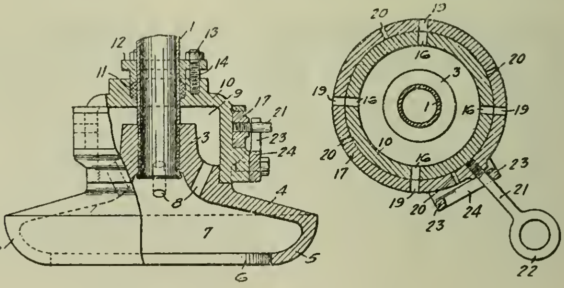


Fig. 34.

The blowhead consists of a bait, 2 (Fig. 34), a pipe, 1, through which air is supplied to the bait, and air ports, 8, in the bait, adjacent to the lower end of the pipe, 1, through which the excess air is allowed to escape. In order to regulate this escape of air, the ports, 8, instead of communicating directly with the atmosphere, open into a hollow casing, 9, from which the air escapes through ports, 16 (Fig. 34), into the atmosphere. A collar, 17, surrounding the casing, 9, is pierced with two or more sets of holes, 19, 20, of different sizes, and these may be brought into coincidence with the ports, 16. Thus, by moving the collar, 17, the area of the ports, 16, and therefore the amount of air allowed to escape, can be regulated. G. D.

65. Drawing Glass Cylinders. William Westbury (U.S.A. Pat., June 24th, 1919, Nos. **1307943** and **1307946**. Filed October 3rd, 1917, Nos. 194495 and 194497).—The inventor explains that, in drawing glass cylinders, two different methods are employed. In one, the cylinder is drawn directly from the body of metal in the tank through an opening in the topstone of a forehearth or doghouse. In the other method, the metal is ladled from the tank into a pot heated by a separate furnace. In order to combine the advantages and to avoid the disadvantages of both methods, it is proposed to employ a pot, 3 (Fig. 35), mounted on trunnions which can be dipped, through an opening, 5, in the topstone of the tank, into the metal, 2. It is then raised to fill the opening, 5, and the drawing proceeds. The pot, 3, preferably consists of two pots placed base to base, and is reversed before filling. Thus, while a cylinder is being drawn from one pot, the "aftermath," or chilled glass, which remains in the pot after drawing is being melted out of the other pot. G. D.

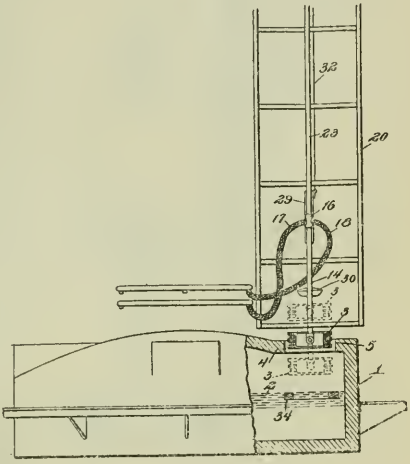


Fig. 35.

66. Drawing Glass Cylinders. Otis A. Wells (U.S.A. Pat., April 22nd, 1919, No. **1301771**. Filed October 7th, 1914. No. 865490).—The invention relates to the method of making glass cylinders by drawing, and the specification discusses at length the relative advantages and disadvantages of the "hot bait" method, in which the bait is preheated to the point at which it will weld to the glass, and the "cold bait" method, in which the bait is used at a temperature much below the welding point. The inventor has discovered that the best results can be obtained by using the bait at a temperature intermediate between those employed in the two processes mentioned. Accordingly, the present invention consists in using a heated bait having a temperature below that at which the glass will fuse thereto, but high enough to have the same radial contraction during the drawing process as that which occurs in the novel or rim of glass which is anchored in the flange of the bait. G. D.

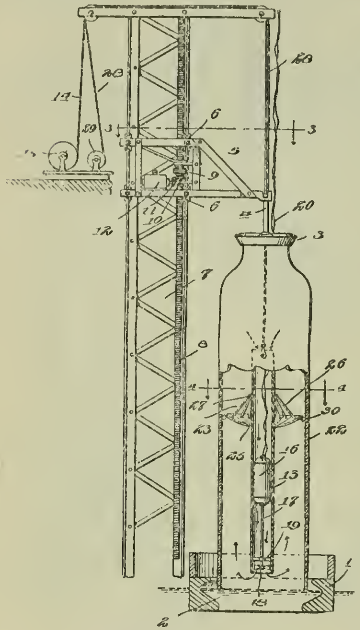


Fig. 36.

67. Drawing Glass Cylinders. William Westbury. (U.S.A. Pat., June 10th, 1919, No. **1306651**. Filed January 26th, 1916, No. 74473).—The invention consists of a process of drawing which is designed to avoid the defects that occur when it is attempted to draw cylinders of large diameter. An open bait, 3 (Fig. 36), is used, and the cylinder is drawn around a tube, 13, which is suspended with its lower end a few inches above the surface of the metal, 2. Within the tube, 13, a fan, 19, operated by a motor, 16, sucks air downwards, so that there is a complete air circuit within the cylinder being drawn. A centring device, 23, which opens and closes like an umbrella, bears lightly against the inner surface, 22, and thus prevents the tube, 13, from swinging. G. D.

68. Drawing Glass Cylinders. W. L. Monro (U.S.A. Pat. February 25th, 1919, No. **1295348**. Filed July 24th, 1915. No. 41686).—Relates to the method of drawing glass cylinders by the "cold bait" process, that is, the process in which the bait, when

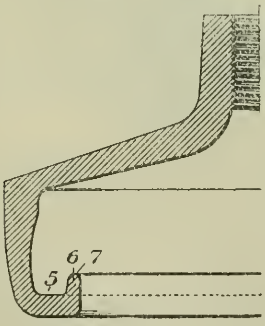


Fig. 37.

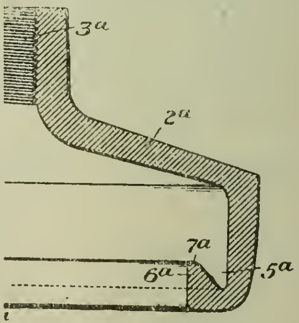


Fig. 38.

inserted in the metal, is at a temperature considerably below that at which the glass fuses on to the metal of the bait. The specification explains that hitherto it has been considered that the flange, 5 (Fig. 37), of the bait, which anchors the glass, should have an inner wall with little or no inclination to the horizontal. According to the present invention, the inner surface of the flange, 6*a* (Fig. 38), is inclined at an angle of at least 45° to the horizontal, and may be at an angle of 90°, as shown in Fig. 37. G. D.

69. Splitting Glass Cylinders. JOHN MURPHY (U.S.A. Pat., June 17th, 1919, No. **1307209**. Filed May 10th, 1918. No. 233687).—A stand for supporting cylinders during splitting consists of side members, 2 (Fig. 39), connected by strips, 3, of flexible material which carry the cylinder, and anti-friction rollers, 4, which can be raised or lowered by means of a treadle. When the rollers are raised, they lift the cylinder off the strips, thus enabling it to be turned easily for selecting the line of splitting. G. D.

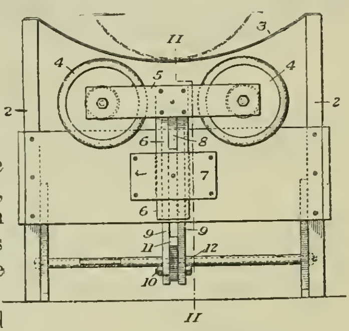


FIG. 39.

70. Perforating Glass. BRITISH THOMSON-HOUSTON Co., London (GENERAL ELECTRIC Co., Schenectady, New York, U.S.A.) (Brit. Pat. No. **119589**.) (January 4th, 1918, No. 238).—Glass whilst in a plastic condition is perforated by pressing through it one or more pins made of a metal which is not wetted by the glass, such as tungsten or molybdenum. In the arrangement shown, a series of pins are placed in apertures in a refractory block, 3, and a bead of glass, 7, carried by a stem, 8, is pressed on to the bent upper ends of the pins in a mould, 5, supported on a refractory plate, 6, heated by a burner, 9. Fig. 40 shows the device thus

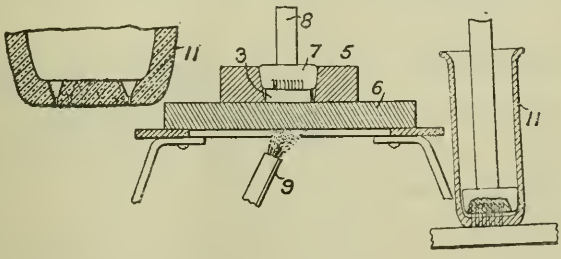


FIG. 40.

formed used for forming perforations in a die, 11. If the perforation is effected when the glass is at the right temperature, coned perforations are produced. H. G. C.

71. Device for Splitting Glass. H. F. HITNER (U.S.A. Pat., March 11th, 1919, No. **1296661**. Filed June 26th, 1916. No. 105926).—The invention consists of a device for splitting glass, particularly glass cylinders, by electricity. The frame 1 (Fig. 41), of the device consists of channel iron shaped as shown, a strip, 4, of refractory insulating material, such as asbestos, being fitted into the channel. A block, 11, is secured to, but insulated from, the frame, and another block, 8, is attached to a spring, 6, secured to the end of the frame. A strip, 5, of nichrome is secured to the blocks, 8 and 11, and is thus tensioned by the spring, 6. In order to prevent the strip from burning off at its ends, it is fastened to the blocks in the manner shown in Fig. 42. The turned-up end, 7, of the spring, 6, forces the strip into a groove in the block, 8, when the screws are tightened. The wires of the cable, 22, are connected to the frame, 1, and to the block, 11, respectively, and a guard, 38, secured to the handle part of the frame prevents the wires from being broken off from their terminals. G. D.

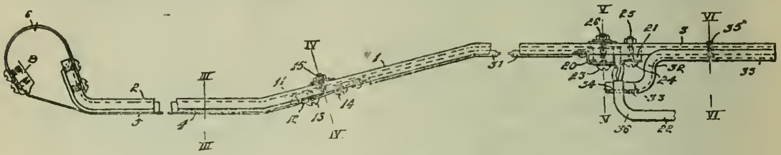


FIG. 41.

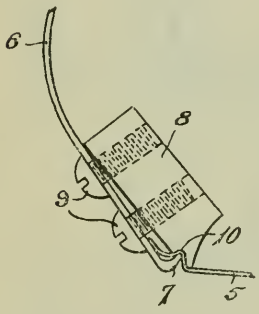


FIG. 42.

72. Handling Sheet Glass. JOHN A. BECHTEL (U.S.A. Pat., June 17th, 1919, No. **1306993**. Filed June 21st, 1918. No. 241278).—A stowing tool, shown in cross-section in Fig. 43, for pushing sheets or plates of glass through the lehr, consists of a length of I-beam, 2, to the flanges of which channel irons, 4, are secured. Detachable handles, 4, engage studs, 5, on the inside of the blade, so that the blade can be reversed in use to prevent warping. G. D.

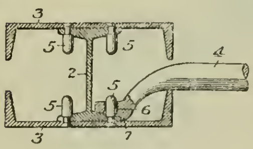


FIG. 43.

73. Apparatus for Moulding Plate and Sheet Glass. EMIL G. JOHANSON (U.S.A. Pat., March 18th, 1919, No. **1297566**. Filed July 26th, 1917. No. 182975).—Relates to an apparatus for impressing a design on a flat plate or sheet of glass. A mould plate, 28 (Fig. 44), impressed with a suitable design, is supported on a stand, 10, and is heated from beneath by gas jets, 12. A hollow roller, 19, heated internally by gas jets, 20, is journalled at one end in a carriage, 18, which can be traversed along guiding rods, 15, 16, by a leading screw. In use, a plate of glass in a softened condition is laid on the mould plate, and the roller, 19, is lowered by a screw device actuated by a hand-wheel, 30, to press the glass. The roller is then traversed along the glass plate, which thus receives the design on the mould plate. The use of the device for the production of a plurality of headlight lenses in one operation is suggested. G. D.

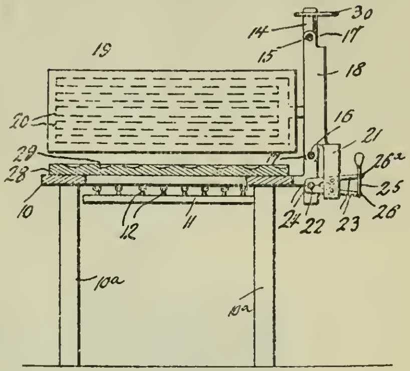


Fig. 44.

74. Casting Plate Glass. W. L. Clause (U.S.A. Pat., April 1st, 1919, No. **1298893**. Filed January 12th, 1912. No. 670740).—Relates to a means of casting plate glass from a tank. The tank comprises a melting chamber, 7 (Fig. 45), and a refining chamber, 8, and the chamber, 8, is provided with a spout, 10, beneath which a casting table, 11, with the usual roller, 12, is placed. The spout is closed by a gate, 13, and both spout and gate are heated by gas jets, 7. A crane, 19, running on tracks, 20, supports a hoe-like implement, 14, which has a U-shaped end, 22. In use, the rake, 22, is immersed in the metal in the tank and then withdrawn, so as to carry with it a charge of metal, which is spread on the table and is then rolled in the usual manner. G. D.

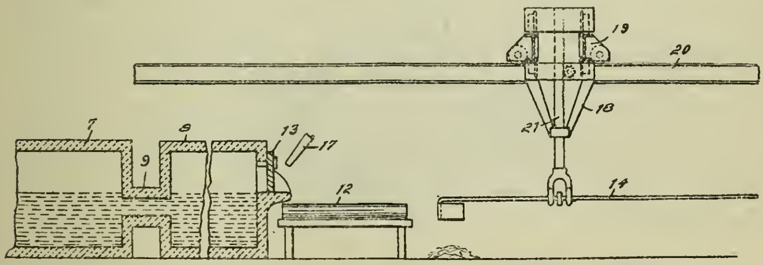


Fig. 45.

75. Drawing Sheet Glass. R. L. FRINK and F. J. FRINK (U.S.A. Pat., April 29th, 1919, No. **1302149**. Filed February 27th, 1914. No. 821396).—Relates to means for melting off the congealed glass which remains in the drawing-pot after a cylinder has been drawn. The apparatus consists of two drawing-pots carried by a frame, 5 (Fig. 46), which is secured to a rotatable shaft, 2. The pots, which are of the type described in U.S.A. Pat. 941512, consist of inner and outer layers, 11, 10, respectively, separated by a layer, 12, of heat-insulating material, and are provided with a central tube, 13, for the admission of air to the draw. A stationary air pipe, 14, positioned beneath the drawing station, has a movable extension, 15, which enables a ready connection to be made with the pipe, 13. Diametrically opposite the drawing station is the draining station, consisting of a chamber, 18, of brick having one side open and provided with burners, 19. Thus, when the pot is positioned in front of the chamber, as shown, gas flames will be directed into its interior, and the glass will melt and run down into a trough. A cam, 30, and a crank, 31, actuate racks, 26, which tilt the pots as the latter are moved to and from the chamber, 18. G. D.

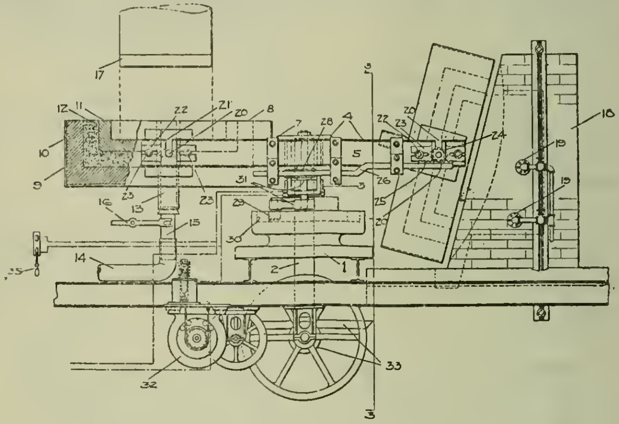


FIG. 46.

76. Drawing Sheet Glass. ROGER S. PEASE (U.S.A. Pat., April 1st, 1919, No. **1299019**. Filed June 5th, 1915, No. 32364). —The invention consists of an apparatus for drawing "cylinders" having flat sides, which may be cut up, therefore, without having to be flattened. Metal from a tank, 1 (Fig. 47), passes into a annular chamber, 6, in a forehearth, 3, whence it passes by means of passages, 7, into a drawing-basin, 5, formed by a conical drawing-ring, 8. This forehearth is described more fully in a co-pending application. The apparatus which forms the present invention consists of four arms, 15, pivoted on a metal plate, 16, which is mounted on a pedestal, 13, extending upwards from the bottom of the drawing-basin. The arms carry rollers, 17, on their outer ends, and may be raised or lowered by means of cables, 18, passing through a central channel in the pedestal, 13. In use, the arms are raised, as shown in dotted lines, and the bait, 22, lowered into the metal. The bait is then raised to draw a cylinder, as usual, but as soon as it clears the top of the forehearth, the arms, 15, are lowered, so that the rollers, 17, press the cylinder outwards. The cylinder, being pressed outwards at four points only, is stretched so that its walls between the rollers become flat, and the result is a "cylinder" which is square in cross-section. In a modification, the rollers and arms are replaced by bars of basswood, soapstone, or copper. In a further modification, shown in Fig. 48, the glass is drawn through a forming-member, 28, square in cross section, consisting of an undercut frame of basswood, soapstone, or other

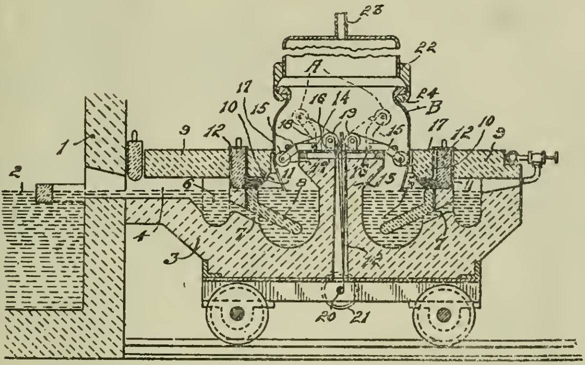


FIG. 47.

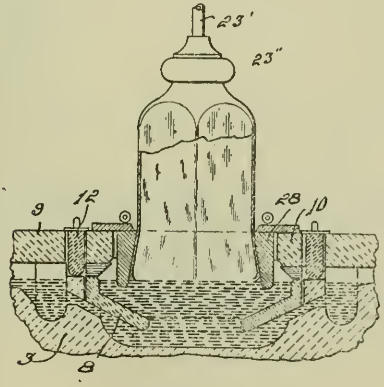


FIG. 48.

suitable material. This frame flattens the "cylinder" as it is being drawn, the glass being pressed against the inner face of the frame by air pressure supplied to the interior of the "cylinder" by means of a pipe attached to the bait. G. D.

77. Automatic Take-in. Richard La France (U.S.A. Pat. No. **1296818**, March 11th, 1919. Filed September 15th, 1913. No. 789779).—Relates to a device for automatically taking-in bottles and stacking them in rows in the lehr, the device being designed particularly for use with the Owens machine. The device is shown in plan in Fig. 49. The bottles as they fall from the machine slide on to concave holders, 3, which are mounted on a horizontal travelling sprocket chain, 7. The holders are carried in front of a reciprocating member, 16, which pushes the bottles on to similar holders, 27, carried by a sprocket chain, 26, which travels across the front of the lehr, so that the bottles will be arranged in a row across the front of the lehr. When a sufficient number of bottles are arranged on the holders, 27, they are pushed on to a rocking frame, 50, called an "uprighter," which turns through a right angle and deposits the bottles in an upright position on the travelling lehr belt. If desired, the holders, 3, and the chain, 7, may be dispensed with and the bottles delivered direct from the machine on to the holders, 27. G. D.

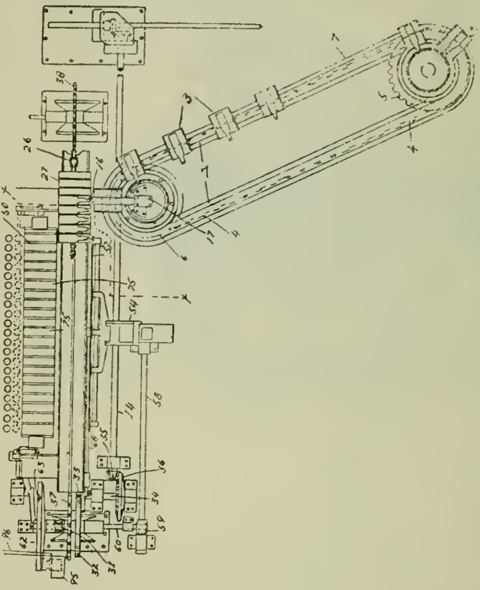


Fig. 49.

78. Glass Stoppering Machine. F. Tweeddale (Brit. Pat. No. **114543**, July 4th, 1917, No. 9615).—The necks of bottles, *f* (Fig. 50), are ground by a mandrel, *d*, fed with emery or other abrasive material. The mandrel, *d*, is secured in a chuck, *b*, on a spindle, b', mounted in a headstock, *a*. The stopper, *e*, is carried in a chuck, *c*, on a second parallel spindle, c', mounted in the same headstock but at a slightly higher level. The stopper is ground by a pair of jaws which encircle it, and are fed with emery, etc. The neck of the bottle which has previously

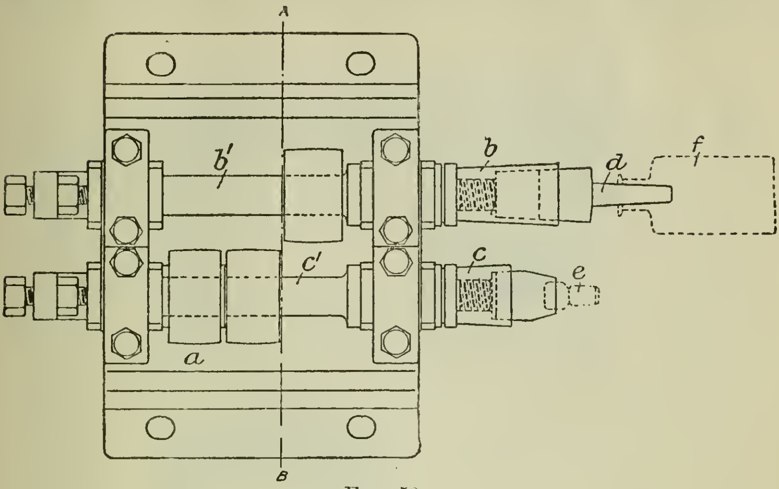


FIG. 50.

been ground by the mandrel, *d*, is then finished off upon the ground stopper.
H. G. C.

X.—Glassware Accessories.

79. Fire Extinction Bottles. G. J. MONEY (Brit. Pat. September 26th, 1918, No. 15696).—Relates to cast-glass bottles or tubes such as are used in chemical fire-extinguishers, and which are formed with thin parts adapted to be broken. The bottles are made of coloured glass, so that the thick and thin parts can be easily gauged by holding the bottle up to a strong light.
H. G. C.

80. A Machine for Washing Bottles, Jars, etc. M. S. CRAVEN, Kingston-upon-Hull (Brit. Pat. No. 119597.) (January 17th, 1918, No. 948).—A rotary soaking-wheel is formed with composite compartments to take two tiers of jars, *J*. Each compartment holds three rows of jars when all are arranged radially, and two rows when the upper tier is arranged tangentially. The compartments are formed by double V-shaped ribs covered with slats, *e'*. The ribs are carried by rotary end frames, *D'*, with intermediate rotary supports. The frame is rotated in the tank, *A*, by toothed gearing, *G'*, operated by a hand-wheel provided with locking apparatus, g'. A perforated frame, F, which covers all compartments except one or two exposed for filling and emptying, can be rotated in the end frames to expose any selected compartments.

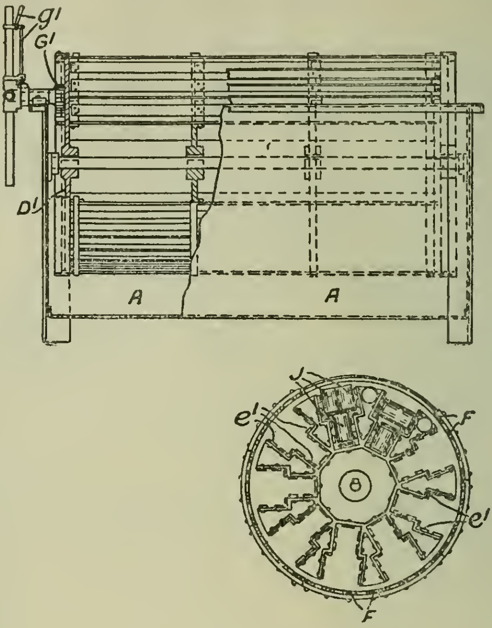


FIG. 51.

H. G. C.

I.—Glass-making Materials.

81. The Importance of Analysis in Purchasing Raw Materials for the Glass Industry. A. Silverman (*J. Amer. Cer. Soc.*, 1920, **3**, 26).—The author desired to direct attention to the variations in composition of raw materials, and the necessity for care as to the composition, form, and size of raw materials and cullet, if uniform products were to be obtained. The chemist should decide whether any new material was suitable before it was substituted for one already used in the batch and giving satisfaction. Cheaper material might be used in certain cases, but the composition of the new material should be known in order that corrections could be made in the batch, so as to give a glass of the original composition. Tables of analyses of various materials were given, both chemical and mechanical analyses being included in the case of sand. The sand to be used should be analysed chemically and mechanically, and the form of the sand grains also taken into account. The density of soda-ash was an important factor, and special note should be made of the sulphate and chloride content of both soda-ash and potash, since the presence of sulphate and chloride might prove objectionable in certain glasses. In the case of salt-cake, knowledge of the iron content was extremely necessary. Alumina and potash, which affected the colour in white glasses, were the important constituents to consider in the case of felspar. The samples of manganese dioxide dealt with showed variations of MnO_2 content between 70 per cent. and 86·25 per cent., and of iron between 0·25 per cent. and 4·0 per cent. The decolorising effect of manganese dioxide did not depend on composition alone, but also on size and form. Analyses of nitres, limestones, limes, and talc were also given.

The author concluded by emphasising the necessity for the purchase of materials on analysis and examination of a sample, and also for the periodical checking of the composition of raw materials. F. W. H.

II.—Glass: Manufacture and Properties.

82. The Cooling of Optical Glass Melts. Howard S. Roberts (*J. Amer. Cer. Soc.*, 1919, **2**, 543).—The paper dealt with the cooling of the glass in the pot in which it was melted; the method involved a greater amount of labour and waste than rolling into a sheet, but it could be made to yield glass of the highest quality.

When the melt was cooled in the pot, the conditions to be sought were (1) that the cooled melt should break into large, reasonably rectangular blocks having smooth faces, and (2) that not much glass should be spoiled by inhomogeneity, that is, by striæ, bubbles, crystals, or devitrification. The author divided the range of cooling into three stages, namely, the stage of fluidity, the "annealing range," and the final stage.

During the stage of fluidity, the glass was apt to be spoiled by striæ, due to convection; by the formation of vacuum bubbles, caused by the premature "setting" of the top surface of the melt; and in certain glasses by the formation of one or more crystalline phases in the glass itself.

Convection might be reduced by insulating the upper portion of the melt with a layer of kieselguhr or other light insulator as soon as the pot was removed from the furnace, and cooling rapidly from the bottom.

Convection could be further reduced by intensive chilling of the bottom of the pot by means of a current of compressed air or a fine stream of water during the last hour before it was removed from the melting furnace. The cooling should be made rapid down to a temperature below that at which there was no further danger of crystallisation or devitrification.

Annealing Range.—The rate of cooling through the second stage determined the size and shape of the pieces into which the melt would break. When cold, the melt was usually found to be cut by cracks of two types; curved cracks, roughly spherical and conconcentric with the centre of the melt, and plane cracks, which divided the melt into large blocks. The spherical cracks were due to decrease of temperature difference, and first appeared below the temperature at which the drop was a maximum; these cracks formed one after another until the temperature gradient had disappeared. The plane cracks seemed to be the result of a difference in rate of contraction between the glass and the pot; the temperature at which they first appeared in a given melt seemed to be nearly independent of the cooling rate. The presence of either type of crack in the melt reduced the tendency of the other type of crack to form. As the fracture due to spherical cracks was rough and the pieces formed were irregular, while that due to plane cracks was entirely satisfactory, it was desirable (1) to maintain the temperature gradient at a low value by slow cooling, and (2) to prevent its decreasing much below its maximum until after the formation of plane cracks had begun by increasing the cooling rate at the proper time.

The cooling rate could be reduced (1) by placing the pot in an enclosed space and heating the air round it, or (2) by surrounding the pot with an envelope of some insulating material, such as sand or kieselguhr.

Variations of these two methods were described, and time–temperature data given.

A. M. J.

83. Applications of the Polarising Microscope in Ceramics. Albert B. Peck (*J. Amer. Cer. Soc.*, 1919, **2**, 695).—The paper gave some account of the methods which were in general use for observations with the polarising microscope. Details were given for the determination of the refractive index of a crushed material, and also for the finding of the proportion of orthoclase, microcline, albite, and quartz in felspar.

The analysis of felspar by the microscope might be done in a comparatively few minutes, whilst the chemical analysis was a matter of days.

The microscope had been used to try to determine the mineral constitution of Portland cement, and the processes taking place in the hydration and setting of it; the presence of free lime in the cement might be detected by the microscope, whereas even its presence could not be detected for a certainty by chemical means alone.

The polarising microscope might be used to study the changes which took place during the burning of porcelain, as well as to follow the progress of vitrification and the solution of the clay and quartz.

The effect on the microstructure of different temperatures of burning had been studied extensively, and also the effect of varying lengths of burn.

The relation of the *sillimanite* which was formed during firing to the quality of the ware had also been the object of investigations. The introduction of small amounts of oxides as additional fluxes had been found to have a very marked effect on the microstructure, which was reflected directly in the transparency of the body.

Comparatively little work had been done in the microscopic study of glazes. In the case of non-crystalline glazes, its use was mainly to detect impurities, such as quartz and albite, in the ground felspar, leading to crazing. In the production of crystalline glazes, it was very useful in determining what mineral formed the crystals. The zinc orthosilicate, *willemite*, was the one most commonly formed, although *cristobalite*, one of the many crystalline forms of SiO_2, had also been identified. Manganese silicates and oxides have been partly identified, and zinc titanate or titanium dioxide crystals were also thought to have been present in some glazes containing those oxides. This field had been investigated so little, however, that it should present possibilities of excellent results.

In glass manufacture, the polarising microscope would show: (1) the solution effects of the glass on the pot walls, (2) during the melting of optical glass, the variation in the refractive index, (3) the efficient mixing of a batch, (4) the mineral composition of stones.

Detailed studies had been made of all types of refractory brick. All steps from the raw material through burning to the finished product, and even on to the product after it had been in use for some time, had been considered.

The field was almost entirely new, and capable of important results in the future. A. M. J.

84. Devitrification of Glass. S. F. Cox (*J. Amer. Cer. Soc.*, 1919, **2**, 576. Contribution to Discussion on an article by N. L. Bowen in *J. Amer. Cer. Soc.*, 1919, **2**, 261, and Abs., *J. Soc. Glass Tech.*, 1919, **3**, 172A).—In a study, by the author and A. E. Williams (*Trans. Amer. Cer. Soc.*, 1916, **18**, 315), of the effect of barium salts on the physical properties of glasses, the effect of increasing barium content on the devitrification tendency was noted. Starting with a glass of the formula $\left.\begin{matrix}0{\cdot}5Na_2O\\0{\cdot}1ZnO\\0{\cdot}4K_2O\end{matrix}\right\}2{\cdot}5SiO_2$, barium oxide was used to replace progressively soda, 0·1 molecule BaO replacing an equivalent amount of Na_2O until all the latter had been eliminated; the zinc and potash were maintained constant throughout. A series would hence consist of six glasses of the same silica content. Seven such series of glasses were made, the silica content increasing by 0·5 molecule in each successive series.

The last glass of the series would hence have the following composition:

$$\left.\begin{matrix}0{\cdot}5BaO\\0{\cdot}1ZnO\\0{\cdot}4K_2O\end{matrix}\right\}5{\cdot}5SiO_2.$$

In the study of devitrification tendency, the method employed was similar to that used by Bowen. Definite heating curves were followed, the temperature being raised on successive heatings until a point well past the deformation point of most of the glasses had been attained. Fifteen of the forty-two glasses, those in the high-silica, low-barium corner of the diagram, showed at 700° surface devitrification, which was increased upon further heating at 800°. All other glasses were entirely free from devitrification—those glasses which showed it did so only on the surface.

The author stated that he was inclined to accept Brockbank's explanation of the surface devitrification—that there was a volatilisation of alkali oxides from the surface, leaving a surface layer higher in silica. The author also attributed the fact that there was so little devitrification to the high potash content and the absence of arsenic from the batches.

In reply, Mr. Bowen stated that none of the glasses mentioned by Mr. Cox had a content of barium disilicate as great as that of the corrected light barium mentioned in his original paper.

The observance of devitrification in the high-silica members was probably due to the separation of silica, not to barium disilicate. The simple explanation of surface devitrification offered by Brockbank could be accepted as more than a possible contributory circumstance in some glasses. Devitrification had been observed to begin at the surface of glasses entirely free from alkalies or any significantly volatile constituents. A crucible full of a glass con taining only CaO, MgO, and SiO_2 frequently showed a surface skin of crystals of *forsterite*, Mg_2SiO_4. A. M. J.

85. A Note on Blue Glass. J. W. Mellor (*Trans. Eng. Cer. Soc.*, 1918—1919, **2**, 478).—An investigation into blue glass for lamp bulbs. When a few per cent. of cobalt oxide were added as colouring agent, it was found that the incandescent filament viewed through this glass appeared to be red. It was therefore decided to attempt to cut out the red rays. Copper oxide was first introduced to mask the complementary red, but was not found very satisfactory. A small proportion of chromic oxide with the cobalt oxide proved perfectly satisfactory, and gave a glass which transmitted only blue rays.

A few glasses (lead–lime–soda) were made up with the proportions of the two oxides as indicated:—

No.		Cobalt oxide.	Chromium oxide.	Copper oxide.	Percentage of mixture for stain.
1	Unstained glass	—	—	—	—
2	Copper–Cobalt series ...	—	—	20	4·0
3	,, ,, ,, ...	5	—	20	5·0
4	,, ,, ,, ...	10	—	20	3·0
5	,, ,, ,, ...	20	—	20	4·0
6	,, ,, ,, ...	40	—	20	3·0
7	,, ,, ,, ...	80	—	20	2·5
8	,, ,, ,, ...	100	—	—	2·0
9	Chromium–Cobalt series	—	20	—	0·4
10	,, ,, ,,	10	20	—	0·6
11	,, ,, ,,	25	20	—	0·9
12	,, ,, ,,	60	20	—	1·2
13	,, ,, ,,	150	20	—	1·7
14	,, ,, ,,	200	20	—	2·2

The glasses were annealed, and thin plates ground from them 0·5 mm. thick, and the absorption spectrum of each glass was photographed by means of a Hilger quartz spectrophotometer, the spark spectrum of nickel being used as a standard. Photographs of these spectra were included in the paper, which showed that mixtures of copper and cobalt oxides cut out the green to red portion of the spectrum, while mixtures of cobalt oxide and chromium oxide cut out the violet and yellow to red portion, until, finally, No. 14, little more than the blue rays were transmitted.

It was noticed that in Nos. 11—14 a tint approaching ruby-red was sometimes developed. C. M. M.

86. The Expansion of Solid Bodies at Low Temperatures. F. Henning (*Ann. Physik*, 1907, **22**, 631).—Many different substances were examined, among them being quartz glass and the Jena glass 59^{III}. Liquid air was used as the cooling agent, and a temperature of -191° attained. A rod of glass, 1 metre long at 16°, contracted 0·877 mm. at this temperature. Quartz glass expanded 0·053 mm. J. R. C.

87. The Thermometric Properties of the Alkali-free Glass 477^{III}. H. F. WIEBE (*Zeitsch. Instrumentenkunde*, 1908, **28**, 293).—A communication from the PHYS. TECH. REICHSANSTALT. The glass was found to be a very good electrical insulator and had a small thermal after-effect. Furthermore, it was good for lampworking, though somewhat refractory. Two thermometers were made of it and graduated from $-2°$ to $102°$ in $0{\cdot}1°$, the length of $1{\cdot}0°$ being 4·4 mm. They were calibrated by the Neumann-Thiesen method, the calibration connection in the middle being found to be $-0{\cdot}375°$ and $+0{\cdot}632°$ for the two thermometers. The depression of the zero after heating to 100° was only 0·014°, which was the least hitherto observed. The glass showed a tendency to crack in this test. The reduction formula to the hydrogen thermometer was

$$t - t_{447} = +0{\cdot}00000336(100 - t_{447})t_{447} - 0{\cdot}000000389(100 - t_{447})^2 t_{447},$$

the corrections being greater than for 59^{III} and the alkali-free baryta-borosilicate 122^{III}, and nearly the same as for a potash glass previously examined. The coefficient of cubical expansion between 0° and 100° was 0·00001842, that for 59^{III} being 0·00001769.

J. R. C.

88. The Linear Expansion of the Scale Glass of Thermometers at High Temperatures. H. F. WIEBE and G. MOELLER (*Zeitsch. Instrumentenkunde*, 1908, **28**, 137).—A communication from the PHYS. TECH. REICHSANSTALT. The two Jena glasses 16^{III} and 59^{III} and four different scale glasses were used. The expansions of the scale glasses, those of the thermometer glasses being known, were determined at 0°, 100°, 200°, and 300°. The coefficients of expansion were found to increase with the temperature, the expression

$$\beta = 10^{-6}\left\{860{\cdot}8\frac{t}{100} + 40{\cdot}0\left(\frac{t}{100}\right)^2\right\}$$

being found for the mean of the scale glasses. β was derived from the formula $\beta = \alpha + \frac{K}{nt}$, where α is the coefficient of expansion of the thermometer glass, K the observed expansion difference for $t°$, and n the length of the tube. J. R. C.

89. The Straining of Large Glass Articles by their Own Weight. E. ZSCHIMMER (*Zeitsch. Instrumentenkunde*, 1913, **33**, 376).—Some recent researches had shown that large pieces of glass could be sufficiently strained by their own weight as to exhibit strong double refraction when viewed between crossed Nicols. A uniformly cooled disc of flint glass, 27 cm. diameter and 3 cm. thick, was fixed vertically in front of a mirror, which reflected a beam of plane polarised light through the disc and on to an analysing prism and a photographic plate. With the plane of polarisation of the light passing through the disc vertically and the Nicols crossed, a symmetrical strain pattern was observed.

The whole apparatus was then turned through 90°, so that the mirror and disc lay horizontal. A similar, but less marked, pattern was observed. The disc was then cemented on to a block of wood with a round hole through it, and a very clearly marked pattern was observed.

From these observations, it appeared that the strain assumed by large glass bodies due to their own weight was very considerable, and must affect the performance of astronomical objectives and large prisms which were kept in fixed positions for a long time.

S. E.

90. Improvement of Glass Surfaces. H. Soar, New Southgate, Middlesex (Brit. Pat. No. **134160**, March 21st, 1919, No. 7041).—The surface pores of translucent substances, such as glass, gems, etc., are impregnated with powdered substances, such as ammonium sulphate, sulphur, realgar, etc., with the view of decreasing the amount of dispersion of light whilst increasing the degree of refrangibility. When applied to photographic and other lenses, it is stated to give greater depth of focus, to reduce absorption, to correct, more or less, for chromatic and other aberrations in unsymmetrical lenses, and to give a flatter field. The lustre of gems, mother-of-pearl, and opals is increased by the process. Fluorescent properties may be imparted to glass, etc., by impregnating the surface with a fluorescent powder, such as quinine sulphate.

H. G. C.

91. Arsenic in Glass. S. R. Scholes (*J. Ind. Eng. Chem.*, 1912, **4**, 16).—Opinions as to whether the arsenic used in glass-making remained in the finished glass or not were very conflicting. Samples of a soda–baryta glass of fairly high alkali content, and a lead–potash glass for cut-glass ware, were analysed, and it was found that the greater part of the arsenic introduced remained in the glass, almost all of it being in the quinquevalent state. The raw materials used for these glasses contained 0·3—0·5 and 0·45 per cent. of arsenious oxide, reckoned on the quantity of glass produced.

V. D.

92. Notes on Sheet and Plate Glass Manufacture. E. H. Bostock (*J. Amer. Cer. Soc.*, 1920, **3**, 35).—The history of the sheet-glass industry in America was outlined from its establishment in the early part of the nineteenth century. The Belgian tank method of melting was introduced in 1888 and mechanical production in 1894, the process being a reproduction of the methods used by the hand blower. That method held sway at the present time, but many attempts had been made to produce the sheet directly from the molten metal. The most successful appeared to be the development of the Colburn process by the Owens Company. It was necessary to eliminate the "wave" in the glass introduced by lack of homogeneity, caused by strains produced during the turning from cylinder to sheet form, and, in the Colburn process, by the strains caused during the change from the vertical to the horizontal motion. In the author's opinion, extrusion rather than drawing appeared to offer the best solution of the difficulty.

Pure materials and natural gas had enabled manufacturers to produce excellent window glass without the use of decolorising agents, though the traces of impurities caused the glass to be of various green, yellow. and blue tints. The Belgian fluted glass used in reflected lighting was flattened in kilns heated by artificial gas, and the "sulphur" film deposited reduced the reflective power when the glass was silvered. The use of natural gas enabled American producers to avoid this difficulty. The making of coloured glass sheet had introduced complicated problems relating to the batch composition, to heat treatment (especially in ruby glass), and, in the case of flashed glass, to the coefficient of expansion. The production of sheets of even thickness brought forward manual difficulties, which had not yet been overcome.

Further development was most essential in the production of small articles from sheet glass, such as duplex glass for goggles, wind-shield glass, and glass for portholes; also in machine bevelling and drilling of glass, the absolute control of colour by acid working and staining, and the production of glasses for light filtering, for the exclusion of red and ultra-violet rays, and for *X*-ray work. Glass for directing and diffusing light presented one of the greatest problems. For the first purpose, prismatic glasses with various angles had been unsatisfactory, owing to defects in working and glazing, and the fact that common green glass was often used.

Diffusive glasses required were of two types, one with great specular reflection and one with little reflection, but maximum transmissive and diffusive values. Good colour and lustre of the glass in each case were most essential. F. W. H.

93. The Reactivity of Powdered Glasses. P. NICOLARDOT (*Compt. rend.*, 1919, **169**, 335).—The author had carried out experiments to determine the relative value of several types of glass with regard to resistance to attack by water and by hydrochloric acid. The attack was modified by the fineness of the powdered glass and the nature of the surface. The powdered glass was sieved, the surfaces of the grains used being in the ratio 1 : 2·84 : 12·8. Equal weights of the three kinds of particles were put in platinum crucibles with 300 c.c. of water or $N/10$-HCl and boiled for three hours, the final volume of liquid being 100 c.c. Whole glasses were treated similarly in former experiments.* As before, it was found that the action of water and of hydrochloric acid varied considerably with the chemical composition of the glass, but that it depended largely on the fineness of the particles. Water attack did not vary with the size of the particles as much as that of HCl, the attack in this case generally increasing with the fineness of the powder. Almost all powdered glasses used were attacked more by HCl than by water, contrary to the results obtained for whole glasses. The types of glasses tested included Jena, Thuringen (R), Krasna, Kavalier, Zsolna, and several French ones. It was found that the French varieties were no more attacked by HCl ($N/10$) after autoclave treatment than before, whereas Jena lost weight considerably after treatment in the autoclave. V. D.

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* This JOURNAL, Abs., 1917, **1**, 96.

94. The Relation between the Refractive Index and the Density of some Crystallised Silicates and their Glasses. ESPER S. LARSEN (*Amer. J. Sci.*, 1909, **28**, 263).—The investigation represents an attempt to apply the formulæ of Gladstone and Dale and of Lorenz and Lorentz to the specific refractions both of glasses and crystalline silicates.

The two series of glasses selected for study were the soda-lime–felspar series and the three component $CaO–MgO–SiO_2$ system. The glasses were prepared by melting the pure components, then grinding and remelting them several times in order to secure homogeneity. The scale of melting (presumably small) and nature of the crucible used were not stated. All the compositions recorded in the tables are those calculated from the original batch compositions and not those derived by analysis of the glasses. Glasses rich in CaO and MgO could not be prepared owing to the tendency to crystallise.

The indices of refraction of the glasses were determined by the method of minimum deviation, using lithium, sodium, and thallium lights, the measurements being made on a Goldschmidt two-circle goniometer.

The results for the measurements of the felspar glasses are given in Table I, those for the metasilicates of calcium and magnesium in Table II, and those of the other silicates of calcium and magnesium in Table III. The values N_{Li}, N_{Na}, and N_{Th} are averages of two measurements of the refractive index.

The specific gravities (D) of the glasses were determined on powder of 100-mesh size in a pyknometer, with water or xylene at 25°.

TABLE I.

	Per cent. Albite.	Per cent. Anorthite.	N_{Li}.	N_{Na}.	N_{Th}.	D.
Ab	100·00	0·00	1·48645	1·4890	1·49165	2·382
Ab_2An_1	65·37	34·63	1·5135	1·5166	1·51925	2·483
Ab_1An_1	48·55	51·45	1·52785	1·53075	1·53345	2·533
Ab_1An_2	32·05	67·95	1·5420	1·5452	1·5481	2·591
Ab_1An_5	15·87	84·13	1·55635	1·5600	1·56285	2·648
An	0·00	100·00	1·5719	1·5755	1·5786	2·700

The refractive index increased uniformly with increase in percentage of anorthite, except for the highest member of the series, when the increase in refractive index became greater.

TABLE II.

Per cent. $CaSiO_3$	Per cent. $MgSiO_3$.	N_{Li}.	N_{Na}.	N_{Th}.	D.
100·00	0.00	1·6241	1·6281	1·6317	2·904
95·00	5·00	1·6222	1·62615	1·62995	2·899
85·26	14·74	1·6185	1·62235	1·6258	2·891
74·00	26·00	1·61355	1·61745	1·6210	2·881
64·00	36·00	1·6084	1·6122	1·6155	2·872
60·00	40·00	1·60675	1·6105	1·61395	2·858
53·64	46·36	1 60365	1·6073	1·6109	2·854
40·00	60·00	1·5970	1·6007	1·60375	2·835
30·00	70·00	1·59235	1·5960	1·5992	2·821
		1·5818	1·5855	1·5887	2·879
* 10·00	90·00	1·5815	1·5851	1·58815	2·8795
5·00	95·00	1·5788	1·5822	1·5854	2·777
0·00	100·00	1·5767	1·5801	1·5833	2·7575

* These two determinations were made on glasses from separate melts.

The decrease in the refractive index with increase in $MgSiO_3$ content is regular for all but the extreme members of the series, when the index decreases more rapidly.

TABLE III.

Per cent. SiO_2.	Per cent. CaO.	Per cent. MgO.	N_{Li}.	N_{Na}.	N_{Th}.	D.
100·00	0·00	0·00	1·4566	1·45905	1·4612	2·213
46·50	50·00	3·50	1·6370	1·6410	1·64495	2·953
45·00	40·00	15·00	1·63505	1·6392	1·6429	2·9675
50·20	24·80	25·00	1·61835	1·6225	1·62605	2·9205

The specific refractivity of the various glasses and crystals were computed according to both the formula of Gladstone and Dale and that of Lorentz and Lorenz, and it was concluded that, using either formula, the specific refractivity was sensibly additive for the glasses, and nearly so for the isomorphous series of soda-lime felspars. When crystals were compared with glasses of the same composition, the values differed by as much as 11 per cent., and they were usually higher for the glasses. There appeared to be no reason for the choice of one formula in preference to the other, beyond the fact that Gladstone and Dale's formula was the simpler.

V. D.

III.—Lamp-worked and General Scientific Apparatus.

95. Method of Building up Objects of Quartz Glass. W. S. QUIMBY and F. W. ROBINSON (Hanovia Chemical & Manufacturing Co.) (U.S.A. Pat. No. **1330611**, February 10th, 1920. Filed November 23rd, 1918, No. 263819).—This invention is a new method of building up an object of quartz glass to a predetermined shape and size. The object is built up of quartz powder and an initial nucleus of quartz glass. The nucleus is heated until plastic, and is then rotated in quartz powder, so that an accretion of quartz powder adheres to the hot nucleus. The original piece and its adherent accretion are then re-heated until the powder fuses and vitrifies, thus becoming incorporated in the nucleus. During this operation the plastic work is elongated, so that the added accretion is made to add to the length of the original piece. This lengthened work now forms a new nucleus, and is heated and rotated in quartz powder just as before. The operation is repeated until the successive accretions and elongations have brought the work up to the predetermined size.

Where the nucleus is of tubular form, it is desirable to support the heated and plastic walls. This is done by admitting air under pressure through one end of the tube and sealing up the outlet at the other end. S. E.

96. Sealing Electric Incandescent Lamps. British Thomson-Houston Co., London (Brit. Pat. No. **132638**, October 1st, 1918, No. 15945).—In sealing stems into bulbs, a downward pressure is applied to the neck, 15 (Fig. 52), during heating to cause it to contract on to the flare, 16, of the stem. In the apparatus shown, the pressure is due to the weight of a forked member, 17, pivoted at 20 on a frame holding the upper part of the lamp. The frame and stem-holder may be rotated during the heating. In a modification, there are two forked members, pivoted to opposite bars on the frame. In the apparatus shown in Fig. 52, the stem-holder, 26, has a projection, 28, which preserves an aperture through the stem during jointing of the stem and bulb; an exhaust tube is afterwards sealed to register with the aperture. H. G. C.

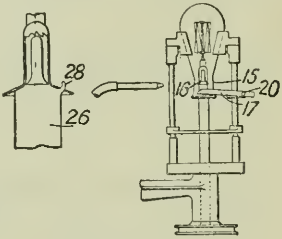


Fig. 52.

IV.—Decorated Glass.

97. Craftsmanship Exhibited in Fine Cut Glass. J. J. Vallely (*J. Amer. Cer. Soc.*, 1920, **3**, 149).—A brief outline was given of the evolution of a piece of artistic cut-glass ware. The essentials in cut-glass ware were a pretty design and good workmanship in cutting and polishing. Cuts should be sharp and true, crossing cuts of exactly the same depth, and all the cuts polished to a sparkling brilliancy. A brilliant polish could be obtained by the use of acids, and the "melted" edges, produced by the fast revolving brush wheel, done away with. Composition emery wheels were superior to stone wheels for most lines of cutting. When the design was pressed into the blank in the plastic state, less cutting skill was required, but usually the ware obtained in this way lacked finish and was a discredit to the industry. The refraction produced in glass cut and polished from the plain blank was almost equal to that of a diamond, but in the case of the pressed design the prismatic effect was practically neutralised, the colour clouded, and the sparkle subdued. F. W. H.

V.—Optics and Optical Instruments.

98. Contributions to the Study of Lenses. G. Maltezos (*Compt. rend.*, 1908, **147**, 736, 850).—These two papers dealt with the equations connecting the distances from a lens of a point source and its secondary images, which are produced by one or more internal reflections; only spherical lenses were considered. In the first paper, the author dealt with thin lenses; in the second, with thick ones. He used the formulæ obtained to determine approximate values of the refractive index and of the radii of curvature when the distances of the object and image have been ascertained. It was suggested that, as the images were very large, they might be used for the observation of microscopic objects. This would necessitate a very brilliant illumination of the object.
J. R. C.

99. The Existing Limits of Uniformity in Producing Optical Glass. J. W. Gifford (*Proc. Roy. Soc.*, 1912, **87**, 189).—Glasses from twenty-seven meltings by different firms were obtained, and three blocks chosen at hazard from each melting and cut into equilateral prisms. The mean refractive index for λ5270 was determined for each of the prisms, and the results reduced to 15°. Detailed results are given, and from these it was shown that the heavy barium crown glasses were those which showed the greatest variation in homogeneity in the same melting.
J. R. C.

100. Some Temperature Refraction Coefficients of Optical Glass. J. W. Gifford (*Proc. Roy. Soc.*, 1915, **91**, 319).—A continuation of the work recorded in Abs. No. 99. Seven additional glasses were examined in the same way, and, in addition, temperature refraction coefficients were given for all the thirty-four. In every case except one the refractive index in air rose with the temperature. This exception was Schott's Fluor-Crown glass, which in this respect was like quartz and fluorite.

J. R. C.

101. A Photographic Objective which contains a Uranium Glass. M. Houdaille (*Zeitsch. Instrumentenkunde*, 1907, **27**, 233; Abs. from *Bull. de la Soc. Française de Photographie*, 1907, **23**, 212).—As colour filters were extensively used in photography, it was desirable to combine the filter and the objective. Accordingly, the convex lens of a photographic objective was made of uranium glass, a piece of which 10 cm. thick absorbed 10 per cent. of the visible and 50 per cent. of the photographically active rays. An objective was also made of a colourless glass of similar composition. With equal exposures of plates, using the two objectives, the negative obtained with the uranium glass was much purer, and the images were equally clear at the edges.

The author stated that it was questionable whether it was advantageous so to combine the filter and the objective. The loss by reflection at the surface of the filter was eliminated, and the stronger absorption of the central portion, owing to increased thickness of the absorbing medium, compensated for the unavoidable decline of clearness towards the edges. J. R. C.

102. Coma in Uncorrected Lens Systems. F. Staeble (*Zeitsch. Instrumentenkunde*, 1907, **27**, 241).—A mathematical discussion of the connection between coma and the sine term.

J. R. C.

103. The Best Rays to Unite at a Common Focus when Designing an Achromatic Objective. J. Wilsing (*Zeitsch Instrumentenkunde*, 1906, **26**, 41).—The author discussed the problem of a doublet, the thickness of the lenses being neglected, and obtained an expression for the radii of curvature of the lenses when two rays were united at the focus, the secondary spectrum being a minimum. Two cases were considered: (*a*) the objective being for visual observations; (*b*) when it was designed for photographic use. Examples were given of the application of the formulæ. The author considered that a tertiary spectrum could not be obtained with only two lenses. J. R. C.

104. On the Spectrum of Elementary Silicon. W. Crookes (*Chem. News*, 1914, **110**, 113).—Great difficulty was experienced in obtaining pure silicon, and this probably explained the fact that lines measured by some observers had not been recorded by others. For the purpose of this research, samples containing 99·56, 99·86, and 99·98 per cent. of silicon were used, the impurities being titanium, iron, and aluminium. Much trouble was caused by a coating of oxide which formed almost at once when fused silicon was used as electrodes with a high-frequency current. The spark becomes much less luminous, and eventually the electrodes were changed every fifteen minutes. The wave-lengths were measured by comparison with the iron spectrum. For two lines in the infra-red, instead of a photographic plate an instrument was used whereby eye observations could be made and recorded; this was fully described.

The wave-lengths obtained were tabulated, those of other investigators being given for comparison. J. R. C.

105. A New Microphotometer for Photographic Densities. W. F. Meggers and P. D. Foote (*J. Optical Soc. Amer.*, 1920, **4**, 24).—The purpose for which the instrument was designed was to measure the photographic densities of narrow spectral lines. It was essentially a micropyrometer, a microscope of high power being employed. The photographic plate was mounted just below the objective, on a horizontal bed, movable with a graduated screw, and was illuminated beneath by a tungsten ribbon lamp. Light transmitted by a small portion of the plate, the image of which was adjacent to that of the tip of the photomer lamp, was matched with equal brightness by adjusting the current through this lamp. It was advantageous to make the measurements with homogeneous light, so the usual monochromatic red glass screen used in optical pyrometers was employed. The instrument was calibrated as a pyrometer by sighting on a black body at a measured temperature, and the relation between the temperature of the source and the current through the photometer lamp sufficient for a match was thus obtained. The measurements of the current required to match against any spectral line and against the clear film were made and converted into "temperatures." From these the true density of the line was ascertained, using Wien's law. The tip of the filament of the pyrometer lamp might be used as a filar in the eye-piece, and the wave-length of a spectral line measured at the same time as its density. Examples were given of the application of the pyrometer to the measurement of the density of spectral lines, to the measurement of energy distribution in a broad spectral line, and to the measurement of the spectral sensitivity of a photographic plate. J. R. C.

106. The Importance of the Nodal Points in Lens Testing. G. W. Moffitt (*J. Optical Soc. Amer.*, 1920, **4**, 1).—The paper dealt with the interpretation of lens measurements made with finite object distance on an optical bench equipped with a nodal slide turntable provided with means for holding the lens and adjusting its position relative to the axis of rotation of the nodal slide. The separation of the nodal points must be taken into account in all cases where the magnification was not zero or infinity, and a knowledge of the positions of these points was essential to the reduction of a set of bench readings. The manner in which these positions could be ascertained was explained, and the necessary corrections were applied to a determination of a focal length as an example of their importance. The formulæ for the field characteristics of a lens were derived, and with these formulæ the reduction of a set of readings led to trustworthy values for the aberrations of the lens under the conditions of the test. J. R. C.

107. The Measurement of Diffuse Reflection Factors and a New Absolute Reflectometer. A. H. Taylor (*J. Optical Soc. Amer.*, 1920, **4**, 9).—In the practical application of light and illumination, it was often desirable to know the reflection factors of various surfaces. No surface obeyed Lambert's cosine law perfectly, and most were very far from being perfect diffusers. No method had been described hitherto which would give accurate results and might be applied to the measurements of surfaces in place. The author described and criticised previous reflectometers, in the majority of which comparison was made with a standard surface such as magnesium carbonate, and then he described his new instrument, with the aid of which absolute measurements could be made. A hollow sphere, with a segment removed, was painted white inside and provided with holes for observation and for the entrance of an illuminating beam. The reflection factor of a surface, placed over the hole produced by the removal of the segment, was calculated from measurements of the brightness of the sphere wall with this test surface in position, of the brightness with it removed, and of the brightness when it was replaced by a surface similar to that of the rest of the sphere. The formula by which this calculation was performed was theoretically derived. The measurements could be made both with the light incident on the test surface, and with it incident on another part of the sphere wall. In order to verify the theory, a graded series of test objects was prepared. Their reflection factors were measured by another method, and then in the two ways possible with this new reflectometer. Extremely good agreement was to be observed between the standard values and those obtained with the author's instrument, using it so that the light was incident on the test-piece. The values obtained in the alternative way were slightly high in most cases, but this was shown to be due probably to experimental error. The reflection factor of magnesium carbonate was measured in four different ways and found to be 99 per cent. The previously accepted factor was 88 per cent., so measurements hitherto made with this as the standard were considerably in error. The effect of specular reflection from the test surface was discussed, and it was shown that this would not cause an error of more than 2 per cent. in the determination of the reflection factor. J. R. C.

VI.—Illumination and Illuminating Ware.

108. Glasses for Protecting the Eyes from Injurious Radiations. W. W. Coblentz and W. B. Emerson (*Technologic Paper* 93, *Bureau of Standards, U.S.A.*).—The object of this paper was to give the general characteristics of certain newly-developed glasses used for protecting the eyes from various radiations, especially the infra-red, or heat rays. Because of the difficulty of producing the same colour in different melts, no attempt was made to give specific data of the transmission for a given thickness of glass. S. E.

109. The Influence of Temperature on the Transmission Factor of Coloured Glasses. M. Luckiesh (*J. Amer. Cer. Soc.*, 1919, **2**, 743).—Hyde, Cady, and Forsythe (*Astrophys. J.*, 1915, **42**, 302), in studying red pyrometer glasses, noted that the transmission factor of the glass was appreciably less for various wave-lengths at temperatures near 80° than at temperatures near 20°.

The author therefore investigated the transmission factor for total visible radiation (not spectrophotometrically) for various coloured glasses at temperatures below which they become self-luminous or plastic, and found that generally the transmission factor was a function of the temperatures.

The illuminants used were gas-filled Mazda lamps operating at normal voltage. The results for ten commercial specimens were given:—

Specimen.	Principal colouring element.	Colour		Relative transmission factors at various temperatures				
		Cold.	Hot.	30°	100°	200°	300°	350°
1	Copper	Medium red	—	100	97	92	87	84
2	Cobalt	Light blue	—	100	101	104	107	108
3	Cobalt	Deep violet	Deep blue	No appreciable change				
4	Gold.........	Pink.........	Violet	100	99	96	94	93
5	Copper......	Bluish-green	Yellowish-green ...	100	98	94	87	82
6	Manganese	Purple ...	Bluish-violet ...	100	97	94	91	90
7	—	Lemon-yellow	Orange ...	100	94	84	75	71
8	—	Dull yellow	—	100	98	94	91	90
9	Copper......	Deep red...	—	100	86	67	50	42
10	Chromium	Yellowish-green ...	Yellow......	100	95	84	72	67

A. M. J.

VII.—Fuels, Refractories, and Furnaces.

110. Producer Gas as Fuel for the Glass Industry. F. J. Denk (*J. Amer. Cer. Soc.*, 1920, **3**, 94).—In advocating the use of producer gas as fuel owing to the decrease in supply of natural gas, the author compared the relative costs of oil and producer gas. The first cost of an oil installation was cheaper than that of a producer gas plant, but the operating cost was much greater. In fact, oil could only compete with artificial gas costing a dollar per 1000 c. ft. Where oil was very cheap and coal very dear, the case might be altered, and in the author's position this point would be reached when, with oil at 4 cents per gallon, coal was 6·25 dollars per ton.

Producer gas was, in most cases, the cheapest fuel for glass factories, whether generated in hand-poked or in automatic producers, always provided the design and handling of the plant were satisfactory. The type of producer installed would depend to a large extent on the men available for operating the plant. There was no advantage in putting down high-grade automatic producers unless a man with technical experience could take charge. Hand-poked producers, managed properly, answered to a certain extent where skilled labour was not available, but they were too much under the influence of the human element. The mechanical producer was the most satisfactory provided that skilled attention was given to it. The main factor in deciding this was that charging changed the composition, quantity, pressure, and temperature of the gas; that is, it influenced everything variable. Frequent charging was better than charging, say, every half-hour. If this latter method were adopted, the temperature of the gas dropped 500° F. in five minutes and required fifteen minutes to reach normal again. The continuous coal feed and ash removal in mechanical producers obviated this difficulty, furnished a gas more uniform in quantity and quality, temperature and pressure, besides generating gas with a higher heating value than is the case with hand-poked producers, the human factor being reduced to a minimum. Whatever type of producer was installed, the best working conditions of the coal used should be determined and the producer operated accordingly. Poor coal was gasified much better in mechanical than in hand-poked producers. In good average practice, the hand-poked, hand-fed producer of 10 feet inside diameter gasified 900 to 1000 lb. of coal per hour, a semi-automatic producer of similar size 2500 lb., and an automatic producer would use 3000 to 3300 lb. per hour.

The bottom of the fuel bed in the producer should be at a certain distance below the level of the ports in the furnace. Then the rising column of hot gases acted as a chimney, a very important fact, since the slack had no effect on the producer owing to the opening of working holes in the furnace. For increasing the efficiency of producers, the gas lines should be watched carefully and kept free from dust; at the gas outlet, the pressure should be equivalent to between 1 inch and 1·5 inches of water, and frequent analyses of the gas should be made, and the amount of carbon dioxide in the gas should not exceed from 5 to 7 per cent. The amount of steam blown in should be just sufficient to prevent the formation of clinker and no more; opening of the steam valve to increase gasification certainly gave more gas, but it was of an inferior quality and the procedure was wrong. The thickness of the fuel bed should be between 2 and 3 feet; the ash bed should be brought to 6 or 7 inches above the top of the blast hood and not nearer, or loss of the blast hood might follow. Cleaning out the producers whenever necessary, at least once a day, reduced the dead resistance in the ash bed, freed the air entry accordingly, and allowed the carriage of a thicker bed of incandescent fuel. Irregular charging and neglect to close up the channels formed in the fuel bed of hand-poked producers admitted air freely, caused the gas to burn in the producer, and gave poor gas to the furnaces. Too thin a fuel bed produced a similar result. Gas lines should be neither too small, so as to obstruct the passage of the gas, nor too large, so as to retard the gas velocity. At any change in direction of flow, dust catchers were necessary, and in these, if the lines were designed correctly and the gas made properly, any soot would be deposited. Frequent blowing out of the lines with air, not steam, was infinitely preferable to burning out.

The author also included a section on regenerating chambers (see Abs., this Journal, 1919, **3**, 263) and an appendix showing comparative calculations of first cost and operating cost for fuel oil and producer gas. F. W. H.

111. The Malinite Process for the Production of Sillimanite Refractories. A. Malinovszky (*J. Amer. Cer. Soc.*, 1920, **3**, 40).—A process was described in detail by which an extremely refractory, neutral body could be produced from any aluminous rock or mineral. The rock or mineral containing the aluminium silicate was smelted in a cupola furnace of special design together with a reducing agent. By varying the proportion of the reducing agent it was possible to regulate the volatilisation of the silica, so that only a portion or the whole of the charge could be converted into *sillimanite*. If only part of the charge were so converted, the remainder gave fused quartz glass or a glass having the same composition as *sillimanite*.

The crushed raw material was mixed with carbon in molecular proportion to the silica content of the rock or mineral, as indicated by the following equations representing the action:—

$$2(Al_2O_3+2SiO_2)+6Fe_2O_3+39C \longrightarrow Al_4C_3+4Fe_3SiC+32CO,$$
$$Al_4C_3+4Fe_3SiC+21O \longrightarrow 2Al_2O_3+4SiO_2+12Fe+7CO,$$

or

$$2(Al_2O_3+2SiO_2)+3Fe_2O_3+24C \longrightarrow Al_4C_3+2Fe_3SiC+2SiO_2+19CO,$$
$$Al_4C_3+2SiO_2+2Fe_3SiC+15O \longrightarrow 2Al_2SiO_5+2SiO_2+6Fe+5CO.$$

Assuming that the equations given were correct, SiC was formed, gave up its carbon, and the silicon left behind burned in the blast to SiO and finally to SiO_2, the action being strongly exothermic. The iron acted as a catalyst in that it promoted the reduction of the silica and accelerated the reaction. If iron were absent, more fuel was necessary, or from 3 to 6 per cent. of iron might be added as an ore or impure clay. The presence of titanium was beneficial, since it hindered the combination of iron with alumina, and hence the iron was left free for reaction with the silica when the mass was boiling.

The fused mass obtained was highly refractory, free from expansion and contraction at any degree of temperature, and did not warp, crack, or spall on change of temperature. Heated in an electric furnace in contact with carbon resister plates at a temperature of approximately 1650°, the malinite brick was unaffected.

A detailed account was given of an examination of the product and of an investigation into the formation of *sillimanite* using pure kaolin, fireclays, and *halloysite*. The author failed to find *sillimanite* in these materials when fired in the kiln in the usual way. Samples of these materials were ground, made into small briquettes, dried, and heated to Orton cone 14 for ninety-six hours. Only in the St. Louis fireclay was any *sillimanite* noticed, and then only in small pockets. These samples were then heated four times to cone 16 and once to cone 18. No *sillimanite* was found in the kaolin or *halloysite*, nor in two fireclays, but the St. Louis and Ohio fireclays contained nests of fine crystals. In the author's opinion, therefore, firebricks, made of pure fireclay free from alkali, required heating above 1400° for a prolonged period and cooling slowly to form crystals of *sillimanite*, and the formation of *sillimanite* crystals in firebricks was produced only by prolonged heating at high temperature, and these were much better developed when the clay contained felspar minerals and micas. An introduction of 25 per cent. of felspar with the samples previously mentioned produced crystals in abundance.

The following analyses, among others, were given of the fused product of the malinite process:—

	From raw *halloysite*.	From St. Louis fireclays.				
		1	2	3	4	5
SiO_2	17·16	32·60	33·10	38·10	36·30	37·50
Al_2O_3	78·39	63·84	63·59	56·17	58·95	57·94
Fe_2O_3	0·89	1·62	1·57	2·61	2·40	2·16
CaO	1·50	0·89	0·63	1·10	0·65	0·80
MgO	0·29	0·32	0·21	0·49	0·22	0·22
TiO_2	—	0·67	0·82	1·12	0·95	1·10
Alkali	0·36	—	—	—	—	—

The author drew the conclusions that it would be impracticable, if not impossible, to convert fireclay into *sillimanite* by the methods employed in the manufacture of silica and magnesite bricks; the microscopic and petrographic examination of the malinite product showed the *sillimanite* produced by this process, free from any flux, to be a stable compound and in comparatively larger crystals than any *sillimanite* crystals yet produced; that no mineral particles remained unaltered, and that this latter fact produced a compound of great resistance towards chemical action and thermal changes.

The paper was illustrated by numerous photographs and photomicrographs. F. W. H.

112. Factors Influencing the Properties of Silica Bricks. I. ALEXANDER SCOTT (*Trans. Eng. Cer. Soc.*, 1918—1919, 481).—The investigation was undertaken to determine the effects on the inversion of the quartz to the high-temperature forms and on the properties of silica bricks generally of some of the chief non-siliceous materials which occur in the rocks used in the manufacture of silica bricks. In the present paper, in addition to the conversion, the properties considered were the apparent and the true specific gravities, porosity, after-expansion, and refractoriness. The method used consisted in bonding as pure a silica rock as possible with a small percentage of other material, firing the mixture to various temperatures, and examining the bricks so made.

The silica rock adopted was vein quartz (although usually it is unsuited for the manufacture of silica bricks) having the following percentage composition:—SiO_2, 99·46; TiO_2, nil; Al_2O_3, 0·20; Fe_2O_3, 0·24; MgO, trace; CaO, 0·13; K_2O and Na_2O, 0·08; loss on ignition, 0·10.

For the making of the bricks the percentage of material of each grade used was:—

Through 4's on 8's sieve	5·5
,, 8's ,, 16's ,,	7·5
,, 16's ,, 40's ,,	9·5
,, 40's ,, 60's ,,	11·5
,, 60's ,, 80's ,,	13·5
,, 80's ,, 100's ,,	15·5
,, 100's ,, 120's ,,	17·5
,, 120's ,,	19·5
	100·0

The bonding materials used were: (*a*) lime (CaO), (*b*) magnesia (MgO), (*c*) alumina (Al_2O_3), (*d*) iron oxide (Fe_2O_3), (*e*) iron oxide (Fe_2O_3) + carbon, (*f*) titanic oxide (TiO_2), (*g*) lime and magnesia, (*h*) lime and alumina, (*i*) lime and iron oxide (Fe_2O_3), (*j*) lime, iron oxide, and carbon, (*k*) lime and titanic oxide, (*l*) magnesia and alumina, (*m*) magnesia and iron oxide, (*n*) magnesia, iron oxide, and carbon, (*o*) alumina and iron oxide, (*p*) alumina, iron oxide, and carbon, (*q*) lime, iron oxide, and titanic oxide, (*r*) Glenboig fireclay, and (*s*) china clay. The amount used was 2·5 per cent. in the case of the simple oxides, 1·25 per cent. of each where two oxides were used, and in (*q*) 1 per cent. of each. Ordinary charcoal was used, the amounts being in (*e*) 2·5 per cent. of oxide and 0·5 per cent. of charcoal, and in *j*, *n*, *p* 1·25 per cent. of each oxide and 0·25 per cent. of charcoal. The approximate size of the bricks was 2 in. × 2 in. × 1 in., and they were made in a vertical tile press. After drying, they were fired in a pottery kiln for twenty-four hours at cone 8, and then fired for the usual period in a silica brick kiln to three different temperatures, namely, cone 14, cone 16, and cone 19. The blocks fired to cone 19 were cut into sections and examined under the microscope, full details of the examination being included in the paper.

The conversion of the quartz was influenced by the nature and amount of the non-siliceous materials present, the grain size of the quartz, and the temperature and duration of firing. Results showed that the conversion could be increased considerably if the firing temperature were increased. The author held that the conversion would be greatest when the surface of the quartz exposed was a maximum, that is, when the grain size was a minimum, for the quartz seemed to be converted mainly through the agency of the bonding material, which dissolved the quartz and reprecipitated it as *cristobalite*.

The determinations of the true and apparent specific gravities were carried out by the methods described in the Standard Specification of the Institution of Gas Engineers. In most cases the true specific gravity tended to vary directly as the firing temperature, while the apparent specific gravity followed a similar course. The true specific gravity might be assumed as giving a qualitative idea of the extent of conversion, but the quantitative relation was only approximate.

From the results of the porosity tests, the writer divided the blocks into two groups, those in which the porosity varied irregularly with the firing temperature and those in which it varied regularly.

After-expansion was determined by heating blocks of known size to cone 16 for two hours. Another set of samples was then tested by heating to cone 26 for four hours. The author pointed out that the after-expansion was mainly due to the change of volume during the conversion; hence, where the rate of conversion was rapid at the temperature of the test, the after-expansion was high, and where the rate was slow, the after-expansion was low.

For the spalling test, the author followed a method proposed by McDowell, by which the relative tendency to spalling was measured by the percentage change in the modulus of rupture after heating to 600° and cooling in air, and he obtained results which were fairly satisfactory.

The tests on refractoriness were carried out by the usual method, and the test pieces subsequently cut into sections and examined under the microscope. The author stated that the results of these refractory tests would be further discussed in the second part of the work, in connection with the refractoriness under load.

In all cases, the results of the tests were set out fully in tables.

C. M. M.

113. Refractory Substances. C. H. SANKEY, Chislehurst (Brit. Pat. No. **133842**, December 19th, 1918, No. 21315).—Waste refractory articles, such as fire-bricks, tiles, saggers, retorts, or the refractory lining of furnaces, kilns, flues, retorts or coke-ovens, which have been calcined in manufacture or use, are ground and mixed with silicate of soda and water, moulded or worked by hand to the required shapes, and fired. The refractory material may be cleaned or washed before being ground.

Reference has been directed by the Comptroller to Specification 376/83.

H. G. C.

114. The Standardisation of Tests for Refractory Materials. III. The Penetrative Action of Slags. (*Trans. Eng. Cer. Soc.*, 1918—1919, **18**, 516).—The action of slags on fireclays and firebricks can be examined in three ways: (1) The clay mixture can be pressed into hollow blocks of the following dimensions: outside, $2\frac{1}{4}$ in. square, $1\frac{1}{2}$ in. deep; inside, $1\frac{3}{4}$ in. square, $\frac{3}{4}$ in. deep. The blocks are then fired to the desired temperature, say, cone 10. When cold, the desired slag is placed in the receptacle and the whole again fired to the temperature of experiment for the given period of time, for example, four hours. When cold, the penetrative and corrosive action of the slag on the clay mixture can be examined by sawing the block across. This method is not applicable to firebricks because of the artificial treatment involved in making the blocks.

(2) A hole, 2 in. diameter and $\frac{1}{2}$ in. deep, is bored in the brick and filled with slag, and fired and treated as in the above case. Neither of these methods gives any idea of the peculiar resistance which the surface skin of a brick offers to the penetrative action of a slag.

(3) Nesbit and Bell's method. A ring of stoneware is cemented to a firebrick by means of a thin film of a mixture of fine grog and silicate of soda. This receptacle is filled with slag and the whole treated as before. The penetrative action of the slag can then be examined by sawing the brick across. This method can be applied generally to firebricks, and gives good results. C. M. M.

115. Notes on New Experiments on Silica Materials. A. Bigot (*Trans. Eng. Cer. Soc.*, 1918—1919, **18**, 362).—The author pointed out that the results of this work showed that silica rocks and products manufactured from them can be subjected to exact tests, which afford an excellent guide to the manufacturer in his choice of raw materials and methods of manufacture. His conclusions were that (1) raw materials which are too pure, such as chalk flints and many type of quartz, are not suitable for manufactured products, because they fall to powder after having been fired to 1450° for four hours. (2) Silica materials containing 2—5 per cent. of a mixture of clay. iron oxide, and a small proportion of lime and magnesia—some quartzitic and quartzose rocks and some dense flints—are suitable for manufacture if their expansion at 1710° is not too great. (3) Silica rocks which contain 3 per cent. of alumina become too fusible after the addition of 2 per cent. of lime, and are not suitable for the manufacture of silica products.
C. M. M.

116. Note on the Casting of Porcelain Glass Pots. J. W. Wright and D. H. Fuller (*J. Amer. Cer. Soc.*, 1919, **2**, 659).—The characteristics of a casting slip, as well as of the fired body, depended, first, upon the composition—the content of grog, kaolin, ball clay, and felspar; secondly, upon the sizing of the grog; thirdly, upon the peculiar physical and chemical qualities inherent in primary kaolins, as differentiated from the secondary ones, and in ball clays against the fire clays; and, fourthly, upon the amounts and proportions of sodium silicate and carbonate of soda. The following mixtures had been used successfully in the Pittsburgh Laboratory for the casting of glass pots:—

Mixture No. 1.

	Per cent.
Whiteware-bisque grog	48
Felspar	7
Kentucky ball clay, No. 4 or No. 6	11
Tennessee ball clay, No. 5	11
Georgia, Florida, Delaware, and North Carolina kaolins, ¼ of each	23

Mixture No. 2.

	Per cent.
Whiteware-bisque grog	48·0
Felspar	7·0
Kentucky ball clay, No. 4	8·5
Tennessee ball clay, No. 5	8·5
Georgia, Florida, Delaware, and North Carolina kaolins, ¼ each	28·0

Mixture No. 3.

	Per cent.
Whiteware-bisque grog	48·0
Felspar	6·5
Kentucky ball clay, No. 4 or No. 6	11·0
Tennessee ball clay, No. 5	11·0
Kaolins, as before	23·5

The mechanical analysis of the grog used corresponded fairly closely with the following sizing:—

	Per cent.
Between the 10- and 20-mesh sieves	30·0
Between the 20- and 40-mesh sieves	40·0
Between the 40- and 80-mesh sieves	17·0
Through the 80-mesh sieve	13·0
	100·0

The physical and chemical qualities of the clays used were of importance with reference to their response to the effect of the alkaline electrolytes. The primary kaolins were most responsive, followed by the secondary kaolins, ball clays, and fire clays in the order given.

The use of a more plastic clay brought about higher specific gravity of the slip, shortening of the time of casting, decreased drying shrinkage, and increased strength. The use of several plastic clays was recommended, so that a slight change in the properties of one would not upset the working qualities of the mixture.

It had been found that the water content should be between

22 and 25 per cent. of the dry weight of the materials; the specific gravity of the slip, 1·90 to 1·95.

The viscosity desired was such that the pot would cast solid overnight in approximately seventeen hours. The higher the viscosity the slower was the casting of the slip, the greater the drying shrinkage, and the longer the time required for drying. With very viscous slips, but little absorption of water by the plaster mould took place, as the mass stiffened too quickly to permit of flow. With such a slip, however, the pot did not become solid for some time.

With a slip of low viscosity, considerable flow occurred, due to the absorption of water, and an undesirable structure might develop. The less viscous slips became solid in a shorter time and showed a lower drying shrinkage.

The amount of electrolyte varied from 0·20 to 0·33 per cent. of the weight of the dry materials, and the best ratio of sodium silicate to the carbonate was 4:3. An increase in sodium silicate decreased the water content, lowered the viscosity, and shortened the time of casting. An excess of it produced flow or laminated structure.

It was found best to dissolve the silicate in the water, add the dry materials, blunge, and then add the carbonate.

The introduction of a small amount (0·01 per cent.) of barium carbonate seemed desirable for the purpose of eliminating the soluble sulphates. A. M. J.

117. A Simplified Apparatus for the Determination of Air in Clay. H. Spurrier (*J. Amer. Cer. Soc.*, 1919, **2**, 490).—A burette was cut off evenly and fused to the shortened tail-piece of a large carbon funnel, which was placed inverted in a litre beaker.

Eight hundred c.c. of water were placed in the beaker and boiled for some time. The funnel was inserted in the beaker, and the burette afterwards filled with water.

The clay blanks were of such a size that they were easily placed in the bell of the funnel. Such a blank was placed in the vessel of water and the bell rapidly lowered over it.

After a few minutes, all the air had collected in the upper portion of the burette, and the volume could be ascertained.

For convenience, charts were prepared showing the percentage of air by volume calculated on the various sizes of blanks.

A. M. J.

118. The Equipment of a Casting Plant for the Manufacture of Glass Pots. Frank H. Riddle (*J. Amer. Cer. Soc.*, 1919, **2**, 647).—The object of the paper was to describe the methods used and plans proposed, through co-operation between the Clay Products and Glass sections of the Bureau of Standards, for a plant suitable for casting ten 600-lb. glass pots per day. A plan for such a plant was described. The pots might be either open or closed; closed pots were cast in two sections, (1) part of the hood and the bottom of the pot, (2) the top of the hood and cover. When properly stiffened, the top was turned over and stuck on to the bottom. The author remarked that one of these pots had been in use with lime-soda glass for a period of sixteen weeks, and had already been charged ninety-six times. A. M. J.

119. Tank Furnace for Making Flint Glass. William N. Mathews (U.S.A. Pat., December 16th, 1919, No. **1324917**. Filed December 3rd, 1918, No. 265115).—The invention consists of a continuous regenerative tank especially intended for the production of lead glass. The furnace is shown in longitudinal section in Fig. 53, and in cross-section in Fig. 54. The batch is melted in "pots" or muffle chambers, which are constructed within an outer body resembling an ordinary tank surface. As shown in Fig. 54, three of such muffles, 1, 2, 3, consisting of side walls, 6, supporting arches, 8, built of tiles, are arranged beneath a crown, 4, the arches, 8, protecting the metal in the muffles from contact with the gases in the combustion chamber, 9. Each "pot" has a dog-house, 12 (Fig. 53), for the insertion of the batch, and it also communicates at its front end with a refining chamber, 13, placed at a lower level, through a spout, 14, which can be closed by a gate, 15. The chamber, 13, also commuuicates by a throat or dog-hole, 16, with a working chamber, 17, whence the metal is taken out through a hole, 18. The three "pots" and their refining chambers are separate from one another, but the working chambers are in communication, so that the metal stands at the same level before all the working holes. In use, only one of the gates, 15, is raised, while the other two are kept closed. A "pot" is charged with batch, which is allowed to found and plain, and the gate, 15, is then lifted to let the metal flow down to the working end. By using three "pots" as shown, it is possible to obtain a continuous supply of metal at the working holes, since when one "pot" is emptied another is ready.

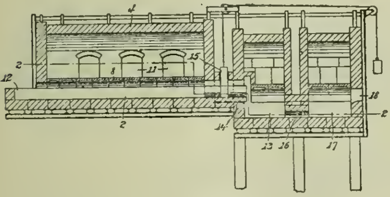


Fig. 53.

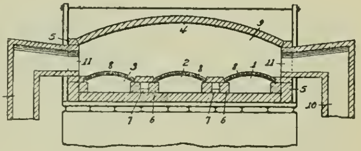


Fig. 54.

U.S.A. Pat., No. **1324918**, granted to the same applicant,

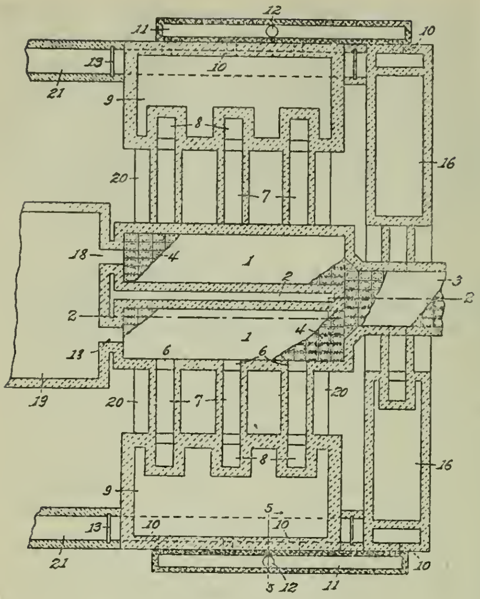


Fig. 55.

describes a tank of somewhat similar character to that described above. As shown in plan in Fig. 55, a melting chamber, 19, seemingly of the usual type, communicates by throats or dog-holes, 18, with two separate refining chambers, 1, which merge at their forward ends into a cooling chamber, 3, that leads to the working holes. The chambers 2, 3, are muffles, as described above, and are built within a combustion chamber, which is heated by gas and air admitted through ports, 6. The bottoms of the chambers, 2, slope upwards, so that the metal in the cooling chamber, 3, being comparatively shallow, is kept at a substantially uniform temperature. G. D.

120. Furnaces for Liquid and Gaseous Fuel. H. Wade, London (Fours et Procédés Mathy Soc. Anon., Liége, Belgium) (Brit. Pat. No. **134169**, May 3rd, 1919, No. 11113).—To enable different methods of heating to be employed alternatively or simultaneously, a gas-producer applied to a re-heating or other industrial furnace is provided with a space above the arch, 2 (Fig. 56), to which liquid fuel may be introduced by an injector, 16, air being supplied at 7 through passages, 5, 6, to burn at will the gas from the producer or the liquid fuel. In addition, a flameless gas burner, 10, may be provided in the bridge between the producer and the

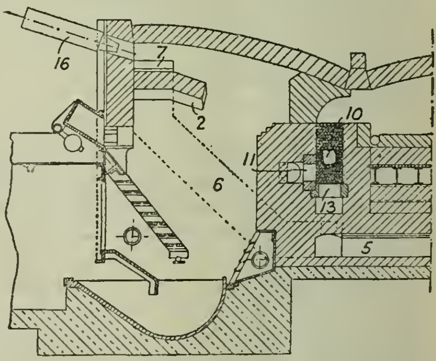


Fig. 56.

hearth of the furnace, gas from an independent source being supplied at 11 to a mass of porous, refractory material, and air from the passage, 5, being supplied at 13. H. G. C.

121. Surface Combustion Furnaces. M. Mathy, Belgium (Brit. Pat. No. **133889**, February 26th, 1919, No. 4855).—In gaseous fuel furnaces in which combustion of a gaseous mixture is effected in a mass of granular, refractory material, the size of the fragments of refractory material is varied at certain parts of the furnace where it is desired to obtain a variation in the temperature, the higher the temperature required at any particular part of the furnace the smaller the size of the fragments of material used. To obtain uniform temperature throughout the furnace, the fragments of refractory material decrease in size from the entrance to the exit of the combustible mixture. Fig. 57 (*d*) shows a crucible furnace in which the crucible is surrounded by fragments of refractory material, which are smaller at the places where a higher temperature is required. The gaseous mixture may enter at the top or bottom of the furnace, To obtain a uniform temperature in this furnace, the refractory material decreases in size towards the top when the gaseous mixture is supplied at the bottom. A muffle furnace is shown in Fig. 57, in which the side, 13, of the article, 12, is heated to a higher temperature than the sides 14, 15 by arranging the refractory material between the walls of the furnace and muffle, as shown. In the muffle furnace shown in Fig. 57 (*b*), the refractory material is arranged so that the highest temperature is at the wall of the muffle. The cover, 21, of the furnace is made hollow and packed with refractory material. The sides, 26 and 27, of the cover, and the corresponding walls, 28, 29, of the furnace, consist of porous plates or plates pierced with holes, which allow for the passage of gases. The lower and upper faces of the cover are of similar material to the sides, 26 and 27, or to the furnace walls. The walls of the muffle shown in Fig. 57 (*a*) and (*b*) may be pierced with holes to ensure more direct heating, or may be of porous material. In the crucible furnace shown in Fig. 57 (*c*), the sides, top, and bottom of the furnace are formed hollow and filled with refractory material in a similar manner to the cover of the muffle furnace shown in Fig. 57 (*b*), and the joining surfaces of the walls are made porous or pierced with holes to

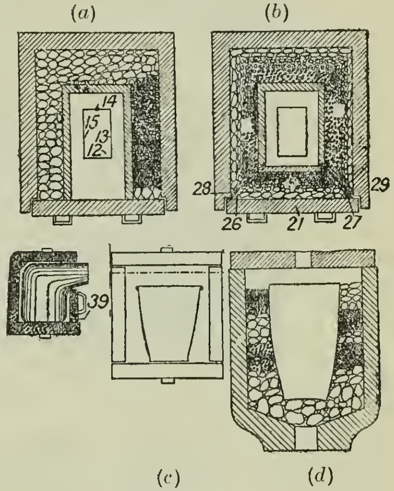


Fig. 57.

permit circulation of the gases. Fig. 57 shows a crucible furnace in which the cover, 39, is similar to that shown in Fig. 57 (*b*).

H. G. C.

122. Electric Furnaces. General Electric Co., Schenectady, New York, U.S.A. (Assignees of E. F. Collins, Schenectady, New York, U.S.A.) (Brit. Pat. No. **133026**, August 6th, 1919, No. 19378. Convention date, September 21st, 1918. Not yet accepted). The heating element for a furnace for heating large objects, such as guns and engine-shafts, consists of resistance strip wound around insulators carried by segmental frames mounted at different heights on the inner wall. As shown in Figs. 58 and 59, the strip, 7, is wound around insulating spools, 13, preferably of alundum, threaded on bolts between frames, 11, 12, which are bolted to columns, 5, built into a fire-brick lining, 4. The furnace is preferably of circular shape with an outer metal shell, 2, a brick wall, 1, and an interposed layer, 3, of pulverulent heat-insulating material. Insulated leads, 16, pass through the wall. The strip is made of an alloy containing 64 to 65 parts of nickel, 18 to 22 parts of chromium, 10 to 16 parts of iron, and 1 to 2 parts of manganese. In a modification, shown in Fig. 59, the columns, 5^1, embedded in the furnace

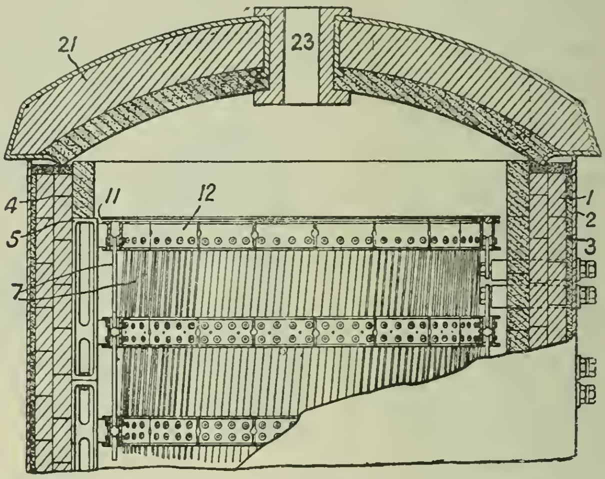


Fig. 58.

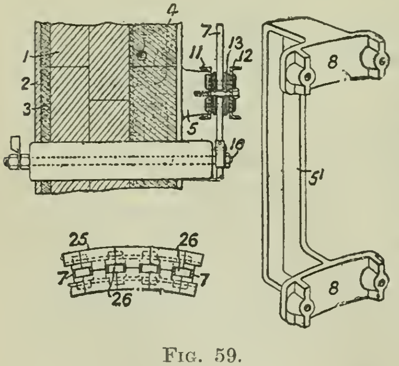


Fig. 59.

lining, are U-shaped with bridges, 8, to which the frames are bolted. The turns of the strip, 7, may be spaced by notched insulators, 25 (Fig. 59), with rectangular blocks, 26, fitting into the notches. A cover, 21, has a central aperture, 23, for a chain supporting the work. H. G. C.

123. Tunnel Furnaces. A. Bigot, Paris (Brit. Pat. No. **132069**, September 19th, 1918, No. 15255).—In a tunnel furnace for the high-temperature treatment of metals, chemical products, glassware, pottery, etc., the tunnel structure is double-walled with an intermediate filling, *h* (Fig. 60), of non-conducting material, and the moving parts, such as the supporting plates, *a*, for the goods, and the balls, *b*, on which they run, are made of highly refractory substances. Fused bauxites, corundum and alumina, carborundum, compounds of chromium, magnesium, and the rare earths, such as the oxides of zirconium, cerium, and the like, are mentioned as suitable. The two walls of the tunnel structure are connected by cross-walls of small thickness, and the filling may be powdered magnesia, silica, and the like, or material in agglomerate form. The tunnel may be heated either internally or by flues in the inner walls, as shown to the right of Fig. 60. In one form of the invention, the supporting plates for the goods co-act with projections from the walls of the tunnels to protect the balls, on which the supports move, from the action of the heat.

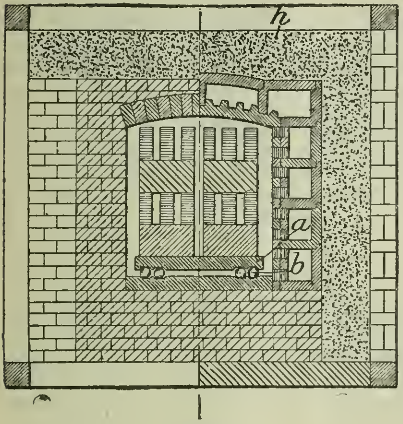


Fig. 60.

H. G. C.

124. Annealing Furnace for Lampworked Articles. G. R. Hughes (Brit. Pat. No. **132852**, September 21st, 1918, Nos. 15364/18 and 9960/19).—An annealing furnace is arranged close to a lamp-workers' bench, *C* (Fig. 61), and is provided with a separate door, *F*, for each worker. When the door is opened, by a pedal, etc., blowpipes are automatically turned on inside so as to heat the air which enters when the door is opened. A separate conveyer track, *J*, may be provided for each door, *F*. The bench, *P* (Fig. 61), which receives

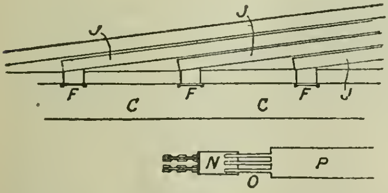


Fig. 61.

the annealed article after its travel through the oven, is provided with projecting rods, *O*, which pass into corrugations of a plate, *N*, carrying the article, and facilitate its removal to the bench, *P*.

H. G. C.

125. Annealing Plate Glass. James W. Cruikshank (U.S.A. Pat., August 12th, 1919, No. **1313222**. Filed December 20th, 1917, No. 208103).—The specification discusses the annealing of plate glass, and explains the difficulty that is experienced in bringing the plates out of the delivery end of the lehr at a sufficiently low temperature so that when exposed to cold-air draughts breakage will not occur, especially in winter. In order to avoid unduly lengthening the lehr, the inventor encloses it for part of its length in a chamber formed by the walls and roof of the glasshouse and dry cross-walls, and replaces the crown of this part of the lehr by a ceiling at some distance above the side walls. The glass radiates its heat to this ceiling, and is further cooled by currents of air in the chamber, the temperature of the chamber being regulated by the gases drawn down the lehr into the chamber by means of a stack having induced draught.

G. D.

126. Lehrs for Annealing Window Glass. James W. Cruikshank (U.S.A. Pat., July 1st, 1919, No. **1308337**. Filed April 18th, 1917, No. 163056).—The bars for shifting sheets of window glass through a lehr consist of two sections, 5 (Fig. 62), of steel bolted together with a strip, 7, of material, such as asbestos, between them. The strip, 7, acts as a nailing strip to enable a second strip, 8, of asbestos to be secured on the upper edge of the bar. This construction enables the asbestos, 8, to be renewed easily when worn, and avoids the necessity for taking apart the entire bar.

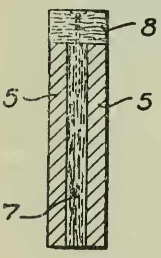


Fig. 62.

G. D.

127. Automatic Lehr. William Stender (U.S.A. Pat., November 25th, 1919, No. **1322735**. Filed April 10th, 1918, No. 227685).—The invention consists of an automatic lehr in which the movement of the bed and of the device for stacking the ware is controlled by the entry of the ware into the lehr. The ware is carried on pans, 12 (Fig 63), which are linked together in the usual way, and are carried through the lehr by a pinion, 14, driven by a motor, *M*, which meshes with racks secured to the undersides of the pans. The front end of the lehr is enclosed by a hood, 6, within which is a horizontal wheel, 20, situated a short distance above the pans. The wheel, 20, is furnished with curved teeth, 22 (Fig. 64), forming pockets, which receive bottles, say, and move them across the bed of the lehr. In use, the bottle, *B*, is inserted in a chute, 19, and as each is pushed inwards it opens a cock that admits compressed air to a cylinder, which turns the wheel, 20, through the space of one tooth. Thus the wheel is moved step by step until a certain number of the pockets have been filled with bottles. Another cock is then opened, admitting air to a cylinder, which moves outwards a curved arm, 32, situated above the rim of the

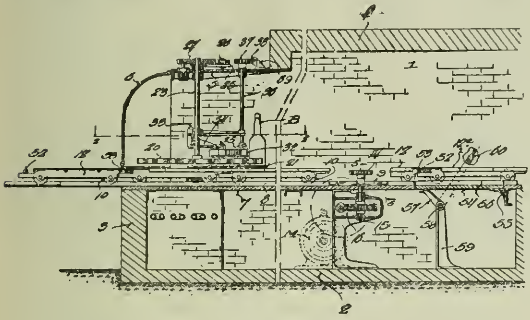


Fig. 63.

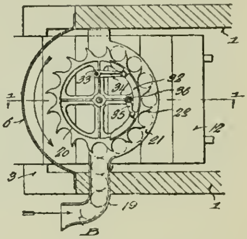


Fig. 64.

wheel, that pushes the bottles out of the pockets on to the pans. At the same time, a switch in the circuit of the motor, *M*, is closed for a short time, so that the line of pans is moved onwards a short distance. When a pan reaches the end of the lehr, it runs on to a section, 54 (Fig. 63), of the floor, which is pivoted at its outer end. This section can be swung downwards by means of a hand lever, 60, and an arm, 57, in order to disconnect the pan from the one behind it. G. D.

128. An Improved Flattening Kiln. Harry E. de Vaughn (U.S.A. Pat., July 1st, 1919, No. **1308341**. Filed October 6th,

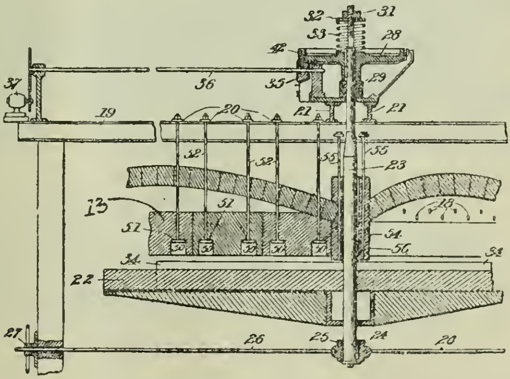


Fig. 65.

1916, No. 124093).—In flattening kilns of the type in which the stones are carried by a revolving table, the driving gear is usually placed beneath the kiln and is inaccessible. The present invention consists chiefly in placing the driving gear above the kiln so that it is away from the heat and readily accessible for adjustment and repairs. The flattening stones, 34 (Fig. 65), are carried by a table, 22, secured to a vertical shaft, 23, on the upper end of which a gear wheel, 28, is feathered. The hub of the gear wheel rests on a bearing, 29, supported by beams, 21, and a spring, 33, is interposed between the hub and a collar, 32, secured to the end of the shaft, 33. Thus the table, 22, is resiliently supported by the wheel, 28, and the level of the table may be adjusted by means of the collar, 32, to vary the clearance between the stones, 34, and the mantel walls, 13. The table is rotated by means of a motor, 37, and hand-driving gear is also provided. In a modification, the weight of the table is supported partly by anti-friction rollers, the height of which can be adjusted from outside the kiln.

The kiln is divided into flattening, annealing, and piling chambers by mantel walls, 13, and the blocks composing these walls, and also the crown of the kiln, are supported by rods, 52, secured to beams, 19, 20, so that the walls and crown are suspended from the beam. G. D.

129. Coke Ovens. La Soc. de Fours à Coke d'Entreprises Industrielles, 94, Rue St. Lazare, Paris (Brit. Pat. July 22nd, 1919, No. **18252**).—In a vertical-flued coke oven having reversible regenerators running longitudinally beneath the ovens the sets of vertical flues are connected to regenerator compartments beneath the ovens on both sides of the heating-wall. In the oven shown, which is so constructed that the heating can be effected either by rich gas supplied cold from mains, 1, 1^1, or by poor gas supplied

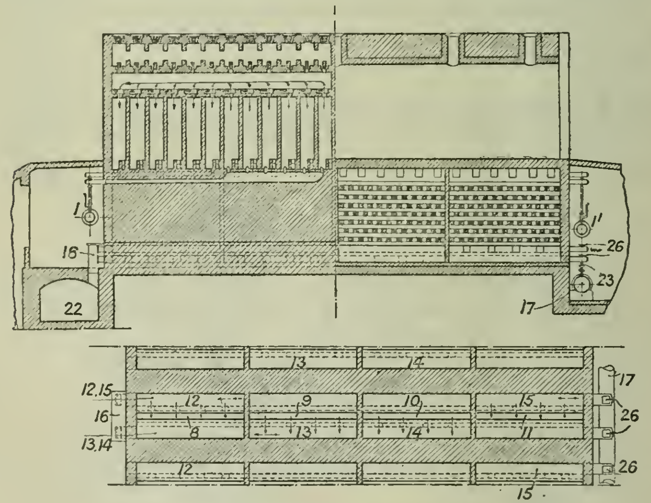


Fig. 66.

through regenerators from the main 17, each regenerator is divided into four compartments corresponding with the four sets of heating flues. At the base of each regenerator are four conduits, 12, 13, 14, 15, opening respectively into the compartments 8, 9, 10, 11, and these conduits are connected at one end to the chimney flue, 22, through a box, 16, and at the other to the poor-gas main, 17, through valved connections, 23. Each conduit has also at this end a controllable inlet, 26, for air. When the heating is effected by rich gas, the air for combustion is heated in the compartments 9, 10 or 8, 11 along the whole bench, according to the phase of operation, while the products of combustion are exhausted through the compartments 8, 11 or 9, 10. When using poor gas, the air will be heated in the compartments 9, 10 or 8, 11 of the regenerator beneath one oven, while the gas is heated in the corresponding compartments of the regenerators beneath the two adjacent ovens.

H. G. C.

130. The Construction of Regenerators. H. HECKER and BENDER & FRAMBS GES., Hagen, Westphalia, Germany

(Brit. Pat. No. **133045**, September 24th, 1919, No. 23518. Convention date, May 2nd, 1918. Not yet accepted).—In a regenerator of the kind in which air ducts are arranged parallel to and on all sides of waste gas ducts, the air ducts are built up of tubular bricks, *a* (Fig. 67), of approximately hexagonal shape in cross-section, and are arranged in horizontal and vertical rows as shown, so as to form waste-gas flues, which are square in cross-section. The bricks are provided with projections at their ends to render the joints between the bricks gas-tight. Waste-gas ducts of rectangular shape may be formed by employing two kinds of bricks of unequal height. The regenerator is enclosed by bricks, *b*.

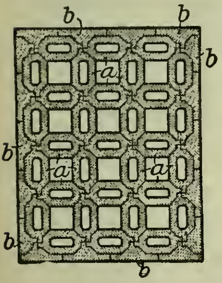


FIG. 67.

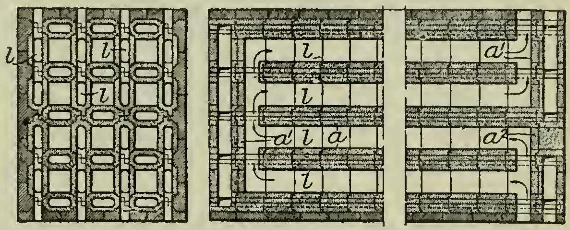


FIG. 68.

(Brit. Pat. No. **133046**, September 24th, 1919, No. 23519. Convention date, September 10th, 1918. Addition to 133045. Not yet accepted).—In a regenerator constructed as described in the parent specification, means are provided for connecting the ends of the horizontal and vertical series of air ducts with one another and with their respective inlet and outlet openings, consisting of bricks of the same shape in cross-section as the bricks forming the ducts, but having openings on one or both of their narrow sides and one end closed. Fig. 68 shows a vertical section through one end of the regenerator, and also a vertical section through a series of vertical air ducts, l, formed of bricks, a. The connections between the ducts, l, are formed by bricks, a^1, a^2, closed at one end, the bricks a^1 having two openings on their narrow faces, and bricks a^2 having one opening only. The inclined joints of the bricks may be stepped as shown. H. G. C.

131. Observation Devices for Furnaces. J. G. W. HINTZE, Sweden (Brit. Pat. No. **131864**, May 29th, 1919, No. 13636).—In order to observe the state of combustion in a furnace or flue with a view to admitting the necessary amount of air for perfect combustion, an air-supply nozzle, d (Fig. 69), is arranged in the furnace wall in conjunction with a funnel, h, forming an injector-like burner, through which a small portion of the furnace gases is drawn. Any resulting flame, which indicates the proportion of unburnt gases present, is observed through a passage, i, provided with a transparent shutter, k. As shown, the nozzle, d, and passage, h, are formed in two blocks supported in the wall, but they may be formed in one block only. The device may also be supported in the wall, so that it may be readily removed through an opening therein. The air-supply passage, f, the passage, h, and the observation passage, i, may be made of tubes and in one piece, so as to form a portable piece of apparatus capable of being readily inserted. H. G. C.

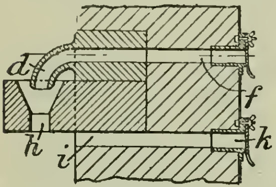


FIG. 69.

VIII.—Chemical Analysis.

132. Note on an Explosion during the Separation of Potassium by the Perchlorate Method. A. F. JOSEPH and F. J. MARTIN (*J. Soc. Chem. Ind.*, 1920, **39**, 94T).—From a solution containing potassium in excess, sodium, phosphates, and silica, the phosphates and silica were removed in the usual way, the filtrate being evaporated to dryness and the residue ignited to expel ammonium salts. Potassium was separated as perchlorate and sodium estimated in the filtrate. During the process the filtrate and alcohol washings containing sodium and excess perchloric acid were evaporated nearly to dryness, and then transferred in a porcelain crucible to the hot plate for completion of the evaporation. After treating the residue with sulphuric acid, the sodium was weighed as sulphate. Although several estimations had been made safely, during the last estimation a violent explosion occurred, when only one or two cubic centimetres of liquid remained in the crucible. It was suggested that some organic matter from the alcohol had not been removed in the early part of the evaporation and that this reacted with the concentrated perchloric acid at the later stage. F. W. H.

IX.—Machinery for the Working of Glass.

133. Machine for Making Glass Vials. W. A. Whatmough, London (Brit. Pat. No. **131532**, December 20th, 1918, No. 21386). —Relates to apparatus for making two vials, etc., from a length of glass tubing. The tubing is placed on two constantly rotating rollers, *A*, *B* (Fig. 70), and two skew rollers, *J*, *K*, mounted on a pivoted frame, *L*, are brought down upon it. It is then centred by two end stops, *G*, *H*, which are moved axially by a right- and left-handed screw, *D*. A blowpipe is directed upon the middle of the tube until it is soft and the stops, *G*, *H*, are separated. The action of the skew rollers, *J*, *K*, draws the tube into two parts, each forming one vial. The rollers, *A*, *B*, are reduced in diameter at *C*, and a flame, *N*, plays on the rollers and tube from below to avoid too sudden heating by the blowpipe. H. G. C.

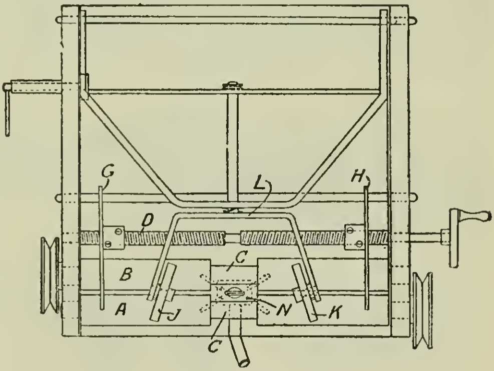


Fig. 70.

134. Glass Blowing Machine. O. Imray, London (Treuhand Vereinigung Akt.-Ges., Berlin) (Brit. Pat. No. **133071**, June 14th, 1917, No. 8559).—In the manufacture of glass objects, such as bottles and preserve jars, a preliminary mould is first charged by dipping it in molten glass and sucking the glass into it, then a head or neck mould is applied, and a part of the glass in the preliminary mould is raised into the head-mould either by further suction or by pressure from below, after which the article is blown in the usual manner. As shown, the glass is sucked into the mould, 1 (Fig. 71), by means of a suction pipe, 4, the end, 5, of which covers the upper end of the mould. The upper end, 7, of the mould is enlarged so as to retain the glass in the mould after the knife, 3, has been removed. After removing the pipe, 4, the head-mould, 8 (Fig. 72), on which rests a hollow head, 9, is applied to the mould, 1, and the air is exhausted through a passage, 13, and through channels, 12, between the ring, 8, and the plunger, 10, so that the head, 14, is formed. The ring, 8, with the blank depending from it, is afterwards placed on a finishing mould, 16 (Fig. 73), the plunger, 10, removed, and air forced into the chamber, 17, of the head, 9. A slide, 20, with a duct, 21, is provided to place the chamber, 17, in communication with the pressure passage, 22.

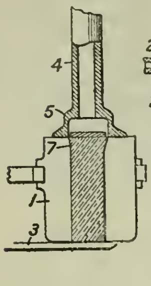


Fig. 71.

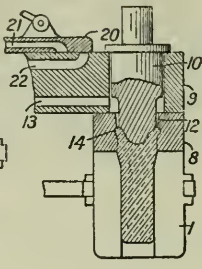


Fig. 72.

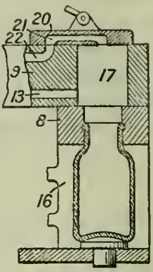
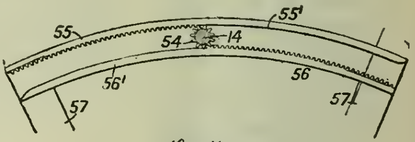


Fig. 73.

H. G. C.

135. Glass Blowing Machines. W. McNeilage, Spotswood, Victoria, Australia (Brit. Pat. No. **132589**, September 9th, 1918, No. 14643).—Relates to rotary-table machines and to means for forming a screw-thread in the mouth of the blank in the parison mould. The moulds, 9 (Fig. 72), of ordinary form, are mounted on a rotary table, 8, to which a step-by-step motion is given. A spindle, 14, carrying a thread-forming plug, 53, is fitted below each mould, 9, and carries a screw, 51, engaging a nut, 12, and a driving pinion, 54. In the rotation of the table, the pinion, 54, successively engages short racks, 55, 56, on the opposite sides of a trough-shaped bracket, 56, fixed to the pedestal of the table by arms, 57. The plug is thus withdrawn at one stage, and at the next stage raised to form the thread. The racks are provided with extensions, 55′, 56′, which act as guides for the pinion. Air for blowing the blank is admitted through a channel, 58.

Fig. 74.



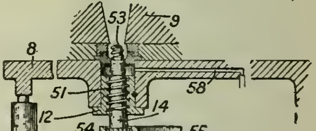


Fig. 75.

H. G. C.

136. Glass Blowing Machine. A. A. MOHN, London (Brit. Pat. No. **734252**, July 31st, 1918, No. 12506).—In a machine of the turn-over rotary-table type, the usual neck, parison, and blowing moulds are combined in a single divided hinged mould, 11 (Fig. 76), which is closed round the blowing nozzle, 10^b. After being charged and inverted, the mould, 11, is closed by a bottom plate, and compressed air is then admitted through the valve, 10^a, to blow the bottle, etc. H. G. C.

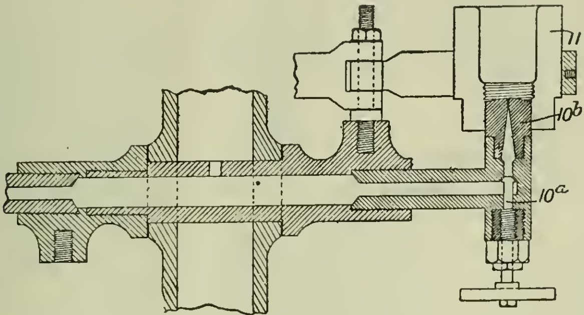


FIG. 76.

137. Glass Blowing and Tempering. M. MATHY, Belgium (Brit. Pat. No. **131843**, March 17th, 1919, No. 6618).—The charge is placed in a cylindrical mould, *M* (Fig. 77), a cover, *T*, is applied, and the bottom, *B*, is raised so as to bring the charge to the top of the mould. A plunger, 15, carried on a bracket, 5, is swung over the mould, *M*, and brought down by a hand-lever, 16, so as to form the initial blow opening. The plunger, 15, is then removed, and a blowing head, 26, brought into place to blow the bottle. The head, 26 (Fig. 78), is carried by a loose double valve, 27. When the head is raised, the valve, 29, prevents the escape of air. When the head is pressed down on the mould top, *T*, the valve 30 closes and the valve 29 opens and allows the blowing air to pass down through ports, *P*. The mould bottom, *B*, is raised by the action of a

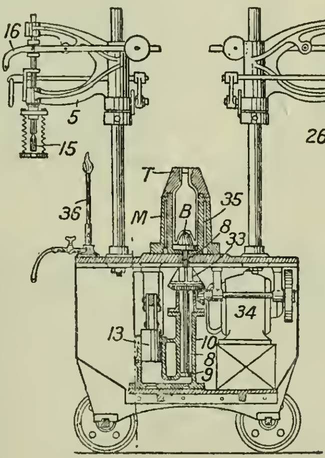


FIG. 77.

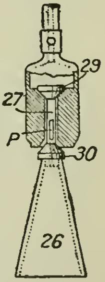


FIG. 78.

hand-operated plunger, 13, which forces oil into a cylinder, 10, and so raises a piston, 9, the rod, 8, of which carries the mould bottom, *B*. An electro-motor, 34, drives a gear, 33, feathered on the rod, 8, and so rotates the bottom, *B*, which has projections to engage and turn the blank during blowing. The plunger, 15, is heated when idle by a burner, 36. The mould is cooled by air circulating through a space, 35. This is stated to temper the bottle.

H. G. C.

138. Glass Blower. E. O. Whitley and E. L. Knowlton (U.S.A. Pat. No. **1309166**, July 8th, 1919. Filed October 21th, 1918, No. 259832).—The object of the invention is to provide a means of gathering and blowing two articles at the same time. Two pipes, 10 (Fig. 79), are arranged side by side, and at their rear end are bent into curved sections, 11, which are united in a common mouthpiece, 13. At the lower ends the pipes are bent away from each other and formed into a U-shaped member, 15 and 16. Connected to the lower ends of the two pipes, 16, are tubular stems, 19, which are rotatable and carry the glass-gathering nozzles, 18. The rotation of these stems is accomplished by turning the handle, 30, secured to the upper end of the shaft, 28. Rigidly fixed to the lower end of this shaft is a large gear wheel, 27, which meshes with gears, 20, on the two tubular stems.

In using this apparatus the nozzles, 18, are dipped into the glass and turned on their axes by operating the handle, 30. Marvering is also done simultaneously by turning the handle. 30, while the hot gathers roll on a slab of marble. The blowing moulds are arranged to suit the distance between the irons so that simultaneous blowing up and rotation of the articles in the moulds are easily accomplished.

S. E.

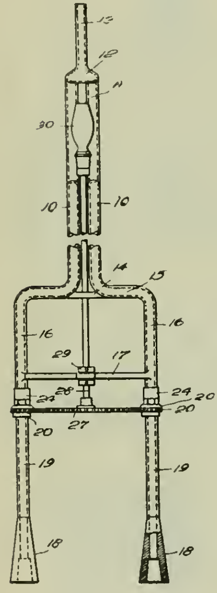


Fig. 79.

139. Bottles with Re-entrant Bottoms. Owens Bottle Co., Toledo, Ohio, U.S.A. (Brit. Pat. No. **132768**, July 21st, 1919, No. 18143).—Relates to the manufacture of bottles having re-entrant bottoms. The parison is partly blown in the parison mould, 15 (Fig. 80), and is formed with a solid annular projection, *P*. It is then inverted, and the blowing completed in a mould having a movable projecting bottom, 34 (Fig. 81), the final shape being shown in Fig. 82. The invention is shown applied to a machine of the kind described in Specification 127995. A cam, 40 (Fig. 82), controls the tilting of the mould bottom, 33, to dis-

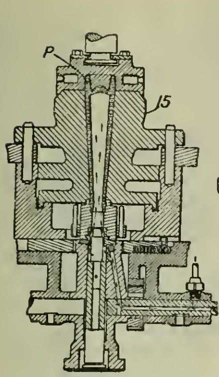


FIG. 80.

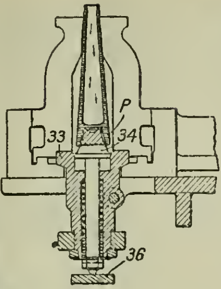


FIG. 81.

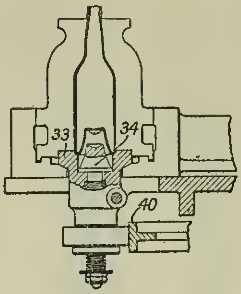


FIG. 82.

charge the finished bottle, and a separate cam, 36 (Fig. 81), operates the movable projecting bottom, 34. H. G. C.

140. Semi-automatic Bottle-blowing Machine. JAMES W. LYNCH (U.S.A. Pat., March 18th, 1919, No. **1297706**. Filed September 28th, 1916, No. 122658).—The invention consists of the parison-forming mechanism of a semi-automatic machine for making narrow-necked bottles. The machine is of the hand-transfer ("one man, one boy") type, but mechanism for blowing the parison in the finishing mould is not described. The specification describes in great detail, and illustrates fully, the valves for controlling the air supply, the devices for timing the operations and regulating the speed, the driving mechanism, the devices for operating the shears, and the lubricating and cooling arrangements. G. D.

141. Automatic Glass Bottle Apparatus. E. ROIRANT St. Ouen, Seine, France (Brit. Pat. No. **134152**, March 10th, 1919, No. 5868).—Relates to automatic apparatus for the manufacture of glass bottles. The movements of the apparatus are timed by adjustable cams on a shaft, 75 (Fig. 83), connected to a continuously-rotating shaft, 86. by a clutch, 104, which is engaged when a finished bottle is ready for discharge, and is disengaged as soon as the next bottle has been blown. The blown bottle remains in the mould during the period of disengagement of the clutch, 104. To allow this period of rest to be varied, a variable-speed friction disk arrangement, 93, 94, is used. The disk, 94, has a pin, 98, which trips a lever, 99, and so engages the clutch, 104, by means of a rod, 100, and bell-crank lever, 101. When the blowing is complete, the roller, *R*, on the lever, 101, enters a recess in a cam, 106, and disengages the clutch, 104, which remains out until the pin, 98, again strikes the lever, 99. By this arrangement, the period of rest in the blowing mould can be varied without altering the timing of the other operations. A ladle, 11, is charged at the opening, 3, and swung about the shaft, 7, to a position below the parison mould by a pinion, 12, and toothed arc, 13. The adjustment of a telescopic rod, 15, connecting the arc, 13, with a crank on a shaft, 75, determines the length of the period of rest at the opening, 3, and below the parison mould. The blowing mould, 33, and parison mould, 39, are hinged on pins, 35, 41, respectively, and work in a manner similar to that described in Specification 112007. Cam-operated compressed air and suction valves, 109, are connected by a pipe, 60, with the neck mould. The cut-off knife, 69, is worked by a spring, 76, and cams on the shaft, 75. H. G. C.

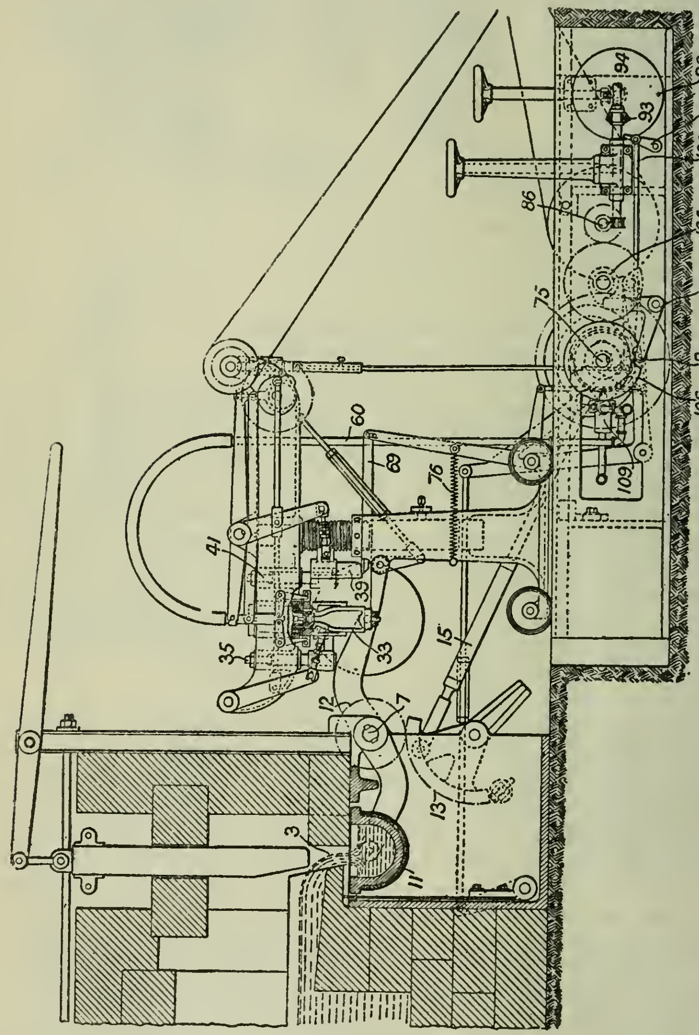


Fig. 83.

142. Process of Making Vacuum Bottles. C. F. P. Anders (U.S.A. Pat. No. **1335544**, March 30th, 1920. Originally filed November 23rd, 1910, No. 593891. Divided, and this application filed February 19th, 1916, No. 79393).—This invention relates to a simplification of the construction of vacuum bottles, which also secures improved heat insulation. The outer vessel is made of cylindrical form having a conical or tapering bottom, 2 (Fig. 84). The inner vessel is substantially the same shape, but has a shoulder, 4, formed by an outward bend near the top. The inner vessel is supported at its free end by a coiled spring, 5, which holds the inner vessel so accurately in position that it is not necessary to have any other supports between the walls of the two vessels, thus reducing heat conduction to a minimum. The open end of the bottle is closed by the hollow stopper, 10, which is evacuated and sealed off in the ordinary way through the projecting point, 13. The sides of the stopper are surrounded by a packing ring, 10, of suitable material. S. E.

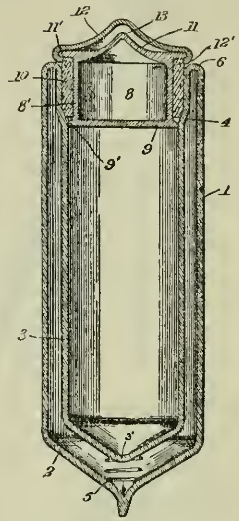


Fig. 84.

143. Drawing Glass Cylinders. James A. Chambers (U.S.A. Pat., July 8th, 1919, No. **1309274**. Filed October 8th, 1918, No. 257405).—In drawing window-glass cylinders from a tank, it is usual to draw the glass through a ring, 9 (Fig. 85), which floats on the surface of the metal, and through an opening in the cover slab, 4, which rests on the drawing ring. When the draw is completed, the slab is raised and the cylinder melted off by gas flames from pipes, 10, but a stump of hardened glass is left in the drawing ring. This stump is re-melted by covering the opening in the slab and allowing the gas flames to continue, but the process results in loss of tune and in other disadvantages. According to the invention, immediately the cylinder is detached, a charge of metal, hotter than the metal in the tank, is ladled into the drawing ring. The hardened stump is thus re-melted and forced downwards out of the ring, and the metal quickly settles down to the proper temperature for drawing another cylinder. G. D.

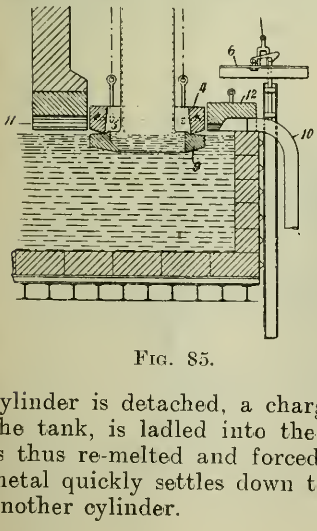


Fig. 85.

144. Drawing Glass Cylinders. Halbert K. Hitchcock (U.S.A. Pat., July 15th, 1919, No. **1309942**. Filed October 8th, 1917, No. 195438).—A take-down apparatus for use in drawing cylinders comprises an inclined frame, 5 (Fig. 86), very similar to the jib of a crane, turning about an horizontal axle, 6, at its lower end, and having a pulley, 23, at its upper end, over which the rope, 7, for raising the bait, 3, passes. When the draw is completed and the cylinder detached from the metal, the frame is brought into a vertical position, and is then swung over backwards, so that the cylinder is supported along its length and brought down into a horizontal position. G. D.

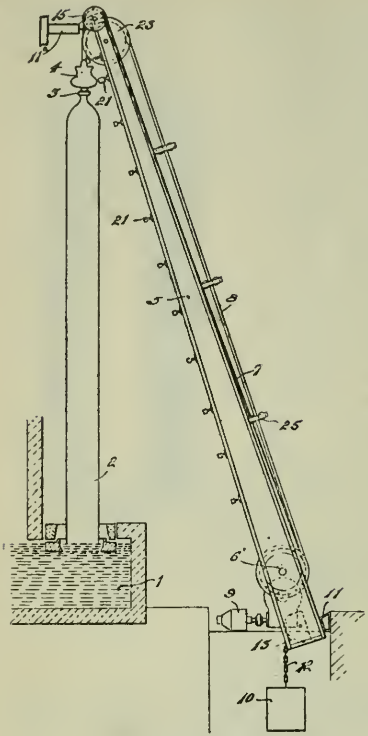


Fig. 86.

145. Drawing Glass Cylinders. Robert W. Hilton (U.S.A. Pat., July 8th, 1919, No. **1309199**. Filed September 9th, 1918, No. 253305).—The invention consists of a furnace for maintaining the temperature of the drawing-pot during the drawing operation and for

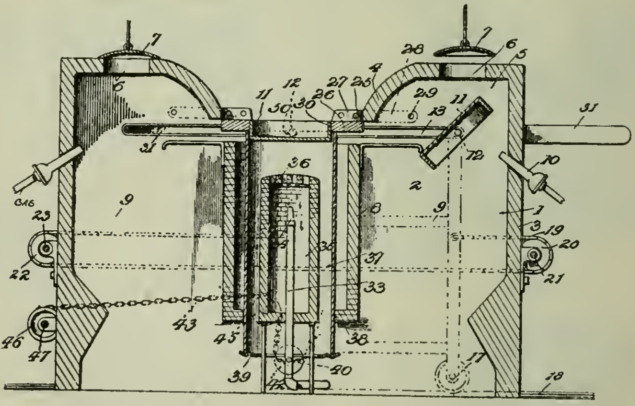


Fig. 87.

melting off the surplus glass after the draw is completed. The furnace consists of a rectangular portion, 1 (Fig. 87), having an inner cylindrical chamber, 8, below the drawing opening, 30. Two pots, 11, are mounted on a sliding framework, which can be moved horizontally to bring one of the pots below the drawing opening and the other pot into one of the end chambers, 9. While in the chamber, 9, a pot is turned about its trunnions, 12, as shown, so that gas flames from a burner, 10, can play on the pot and drain off the surplus metal remaining in the pot after the draw. The opening, 30, is formed in two hinged sections, 26, which fit snugly around the pot, but are lifted when the pot is to be moved. In this position, the pot is heated by a burner, 34, and in order to maintain the metal at a constant temperature, a cylindrical baffle, 37, is raised to fit around the pot. This baffle shields the pot from the heat of the burner 10, and at the same time retains the heat from the burner 34. G. D.

146. **Cutting Glass Cylinders.** Charles T. Moore (U S.A. Pat., August 5th, 1919, No. **1312341**. Filed January 24th, 1919, No. 272848).—A contrivance for cutting up glass cylinders by electricity consists of a pistol-shaped device for tightening a heating wire around the cylinder and for closing the circuit that supplies the current for heating the wire. The saddles that support the cylinder can be lowered individually in order to permit the wire to be moved along the cylinder. G. D.

147. **Drawing Wire Glass.** Irving W. Colburn (U.S.A. Pat., December 2nd, 1919, No. **1323389**. Filed February 28th. 1917, No. 151582).—Wire glass is made by drawing wire cloth, *T*

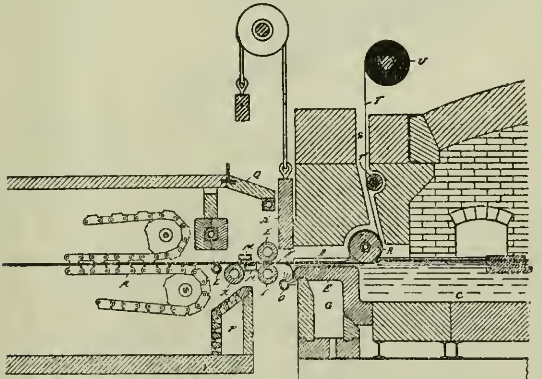


Fig. 88.

(Fig 88), through metal in a tank, the glass with embedded wire being drawn away in a sheet by conveyer chains, *A*. The wire cloth is stored in a roll, *v*, supported above the tank, and passes through a slot, *S*, into metal in a cooling chamber, *C*, thence through a shallow layer of metal, *D*, to the conveyer. G. D.

148. Rolling Plate Glass. WALTER COX (U.S.A. Pat., August 12th, 1919, No. **1313071**. Filed October 14th, 1915, No. 55824).—In order to avoid the formation of "cold spots" in rolling ribbed glass, resulting in a peacock feather appearance, the grooves of the rolling table are made as shallow, wide-angled grooves instead of the narrow-angled grooves usually employed. In the case of glass with about 20 grooves to the inch, the angle between the sides of the grooves and the plane of the sheet should be between 5° and 40°, but an angle of 12½° has been found to give good results. G. D.

149. Machine for Making Sheet and Plate Glass. GEORGE A. SHIELDS (U.S.A. Pat., July 22nd, 1919, No. **1310451**. Filed April 11th, 1918, No. 227978).—The specification described a machine for making plate and sheet glass by flowing metal over the edge of a receptacle on to a moving conveyer, the sheet so formed being scored or marked so that it can be broken up. The metal flows out of the tank over a water-cooled sill, 15 (Fig. 89), and falls in a sheet, 4. The thickness of the sheet is regulated by the temperature of the metal and by the position of an adjustable water-cooled gate, 16, which closes the aperture over the sill. The sheet falls on to an endless conveyer, 6, formed by wooden slats, 27′, attached to endless chains, 24, and is fed by this conveyer into the lehr. On its way down the conveyer, the sheet passes under a water-cooled roller, 28, and each end of the roller is provided with a cutting disc, 33, which trims off the edges of the sheet. Other cutting discs, 34, are also caused to score the sheet longitudinally, and a reciprocating cutter-bar, 38, scores the sheet transversely, these scorings enabling the sheet to be broken up into convenient sizes. The height of the conveyer is adjustable, in order to enable the transparency of the

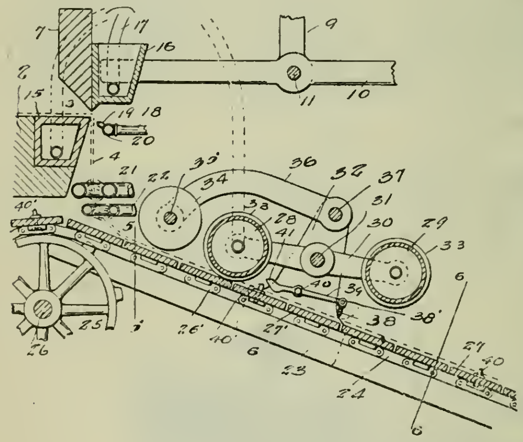


FIG. 89.

glass to be regulated by the length of the drop between the sill, 15, and the conveyer, a longer drop giving a better quality of glass. G. D.

150. Sheet Glass. James H. Campbell (U.S.A. Pat., August 5th, 1919, No. **1312306**. Filed January 7th, 1919, No. 270023). —Relates to the "horses" used in window-glass factories for supporting cylinders while they are being cut up into smaller cylinders, and to that type of "horse" in which the saddles, 10 (Fig. 90), have shanks, 9, supported by springs, so that they can yield to the weight of the cylinder. According to the present invention, the saddles, instead of being independently spring-supported, are mounted in pairs on the ends of levers, 11 (Fig. 90), which are supported at their centres by springs, 14. Thus the saddles are better able to adjust themselves to variations in the diameter of the cylinder, and the weight is more evenly distributed. In a modification, each lever, 11, supports three or more saddles, and is itself supported by two or more springs. G. D.

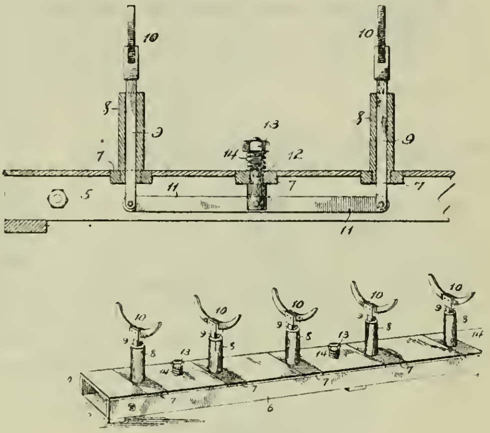


Fig. 90.

151. Drawing Sheet Glass. James H. Campbell (U.S.A. Pat., August 5th, 1919, No. **1312305**. Filed January 3rd, 1919, No. 269524).—In drawing cylinders of glass from metal contained in a drawing pot, the cylinder is liable to move out of centre into contact with the side of the pot, owing to variations of the surface tension of the metal caused by variations of temperature. In order to avoid drawing cylinders of uneven thickness due to this cause, the pot is supported on three levelling screws, so that it may be tilted in any direction. Thus, by raising one side of the pot, the metal on this side is shielded and caused to cool more slowly, and the sidewise movement of the cylinder can be prevented.

It is suggested that a number of pots, say three, could be mounted on a turntable, so that while a cylinder is being drawn from one pot, the others can be under heating covers or furnaces for heating and drawing out the surplus glass. G. D.

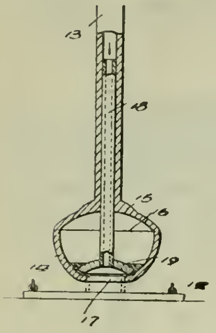


FIG. 91.

152. Drawing Sheet Glass. JOHN R. SCOHY (U.S.A. Pat., July 22nd, 1919, No. **1311137**. Filed October 30th, 1918, No. 260319).—A bait for drawing window-glass cylinders consists of a bowl-shaped member, 14, attached by a cross-piece, 15, to the lower end of a tube, 13, and having an opening, 17, at the bottom. A tube, 18, slides in the tube, 13, and has screwed on its lower end a concave member, 19. In use, the bowl is lowered into the metal, which flows in between the members, 14 and 19, as shown. The metal thus locked between the two members sets at once and enables the cylinder to be drawn immediately, and is said to prevent the cylinder from cracking and falling off the bait. G. D.

153. Making Sheet Glass. T. J. McCOY, U.S.A. (Brit. Pat. No. **132649**, October 11th, 1918, No. 16591).—Relates to apparatus for making sheet glass by causing molten metal to flow in sheet form from the melting-tank on to a conveyer. In the arrangement shown in Fig. 92, the metal, 22, flows from the tank, 20, over a stone, 24, descends vertically, and is received on a series of tablets, 26, moved forward by an endless chain, 31. The tablets carry lateral pins which slide on guides, 28, and deliver the sheet to lifters, 44, from which it passes over a roller. After passing the lifters, the tablets are moved downwards by rotary disks, 116, 118, the pins sliding in guides, and are transferred to an endless chain, 30, which returns the tablets to the front of the tank. The tablets are raised by rotary disks, 112, 114, co-acting with guides, and are returned to the chains, 31, by which they are again carried forward. The tablets are formed with upstanding sides, and carry

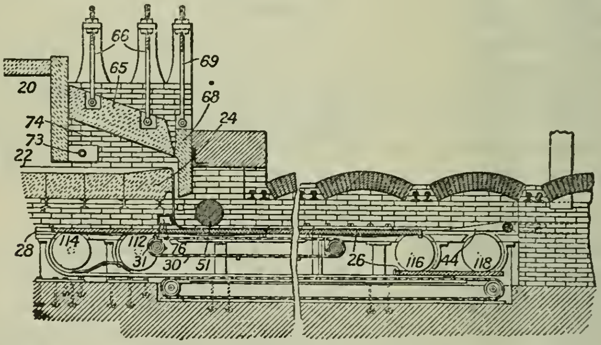


FIG. 92.

transverse blades at their rear edges, so that the glass sheet is severed as it passes under a roller, 51. The tank is provided with an extension chamber, 74, fitted with a cap stone, 65, which can be adjusted vertically and angularly by screwed rods, 66, and a front stone, 68, vertically adjustable by a rod, 69. A gas burner, 73, is arranged in the chamber, 74, and a water duct, 76, is disposed behind the vertical part of the glass sheet. Pivoted guides and retaining plates are provided to ensure that the pins on the tablets take the required paths. Specification 117194 is referred to. H. G. C.

154. Combined Metal and Glass Structure, and Method of Forming Same. W. G. Houskeeper (Western Electric Co.) (U.S.A. Pat. No. **1293441**, February 4th, 1919. Filed January 4th, 1918, No. 210396).—It is difficult to seal one glass to another unless they have approximately the same coefficient of expansion, but in the present case this is done by welding one glass to a sheet-metal member, and thus forming a combined metal and glass structure, to the metal part of which the other glass may be sealed.

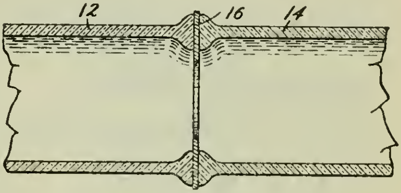


Fig. 93.

In Fig. 93 the two glass tubes, 12 and 14, are welded to the opposite sides of an annular disc, 16, of thin sheet copper or other metal. Although copper has a higher coefficient of thermal expansion than glass, the disc by reason of its thinness and the low elastic limit of the material of which it is formed, is sufficiently stretched by the force of adhesion to maintain the contacting surfaces of the copper and the glass in the same relative positions when cold as when at the welding temperature. In forming such a joint it is preferable that both glass tubes be welded to the disc simultaneously in order that the strains in the disc may be at all times as evenly distributed as possible. In the modification shown in Fig. 94 the glass tubes are welded to separate copper discs (18, 18), and later the copper discs are soldered together; this permits of the ready separation of the tubes whenever it is necessary.

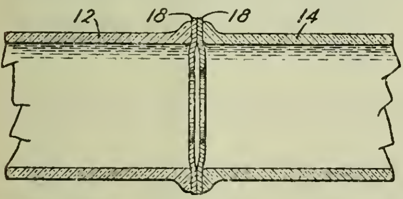


Fig. 94.

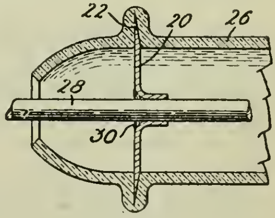


Fig. 95.

The arrangement shown in Fig. 95 shows a sheet metal disc, 20, which has its outer edge formed into a gradually tapering knife edge, 22, around which is welded the glass wall of the container, 26. The edge of this disc is so thin that strains set up in cooling are not sufficient to overcome the adhesion between the glass and the metal of the disc. The main portion of the disc may be of considerable thickness, and may serve as the support of a leading-in conductor of considerable section, such as could not easily be sealed directly through the glass. S. E.

155. Combined Metal and Glass Structure, and Method of Making Same. W. G. HOUSKEEPER (Western Electric Co.) (U.S.A. Pat. No. **1294466**, February 18th, 1919. Filed January 4th, 1918, No. 210397).—This invention relates particularly to structures consisting of glass and metal elements hermetically sealed together, in the form of tubes, and depends on the fact that if the ends of a metal tube be sufficiently thin, it may be welded to a glass tube, and will form a permanently air-tight seal.

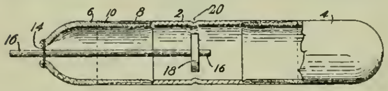


FIG. 96.

In Fig. 96 a piece of copper tube, 2, has its opposite ends surrounding and sealed to the inner ends of the glass tubes, 4 and 6. The metal tube is about $\frac{3}{4}$ in. diameter, and has its end-portions reduced to a thickness of about 0·015 inch for a length equal to at least the diameter of the tube. The end $\frac{1}{4}$ in. of the copper tube is reduced to a knife edge, 10. A section of glass tube having been fitted inside the copper tube, the latter is suitably fixed and heated to a bright yellow heat in a gas flame. When the glass softens it is rolled into contact with the inner surface of the thin portion of the copper tube by a graphite rod.

If the thin portion of the copper tube is not thicker than 0·007 inch, it is not necessary to reduce the end to a knife edge in order to form an air-tight seal.

To form a vacuum lightning arrester, another glass tube, 4, is welded on to the other end of the copper tube, and a small metal disc, 14, is sealed to the reduced end of the tube 6. The disc, 14, carries a conductor, 16, at the inner end of which is a disc, 18, which serves as an electrode. S. E.

156. Making Letter Plates for Signs. ADOLPH W. GAST (U.S.A. Pat., July 1st, 1919, No. **1308408**. Filed February 23rd, 1918, No. 218626).—The invention consists of a process and apparatus for making glass letter plates, that is, plates of glass having letters, designs, or the like appearing in relief on one face and a corresponding depression on the other. The process consists in taking a glass pane or plate of the desired size, heating it to a temperature of, say, 500° F., next passing it through a furnace, by which the temperature is raised gradually until the plate becomes softened, say, 1400° F., then pressing the plate by air pressure against a hot die, afterwards reducing the temperature gradually by passing the plate back through the furnace, and finally allowing it to cool in an annealing kiln. The furnace, 18 (Figs. 97 and 98), is very like a lehr. It is gas heated and has in its heating chamber an upper and a lower track formed by rails, 42. A plate of glass, after being raised to 500° F., is placed in a perforated carrier, 60, which is put into the cooler end of the furnace, shown in Fig. 98, and is pushed along by a bar, 72. The plates move gradually up the furnace until they reach the hotter end, shown in Fig. 97, whence they are drawn on to a table, 80, beneath a heated die plate, 82. The die plate is then pressed firmly against the plate by toggle levers, 93, so as to clamp the plate against the carrier, 60, and also to clamp the carrier against the table, 80. Compressed air is now admitted by a pipe, 88^a, into the space between the carrier and the table, and, since the carrier is perforated, the glass plate is forced by the air to conform to the design on the die plate. The air is then cut off, the die plate is raised, and the table tilted about its pivot so as to shoot the carrier and plate on to the lower of the two tracks in the furnace. The plates are then moved gradually from the hotter to the cooler end of the furnace, whence they are removed to an annealing kiln. G. D.

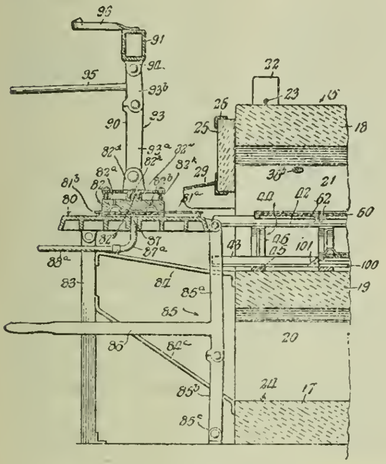


FIG. 97.

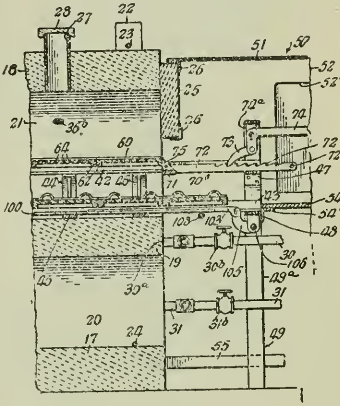


FIG. 98.

157. Shear Mechanism for Glass Working Machines. H. A. GENEST (Hartford Fairmont Co.) (U.S.A. Pat. No. **1331847**, February 24th, 1920. Filed March 28th, 1917, No. 157946).—Machines which are designed for feeding gathers of glass from a furnace are provided with shears which are operated at intervals, cutting off predetermined quantities of molten glass. Whenever the glass-shaping machine is stopped it is desirable that the shear movements should also be stopped, although the feeding operations should be kept going in order to prevent "freezing" of the glass round the outlet.

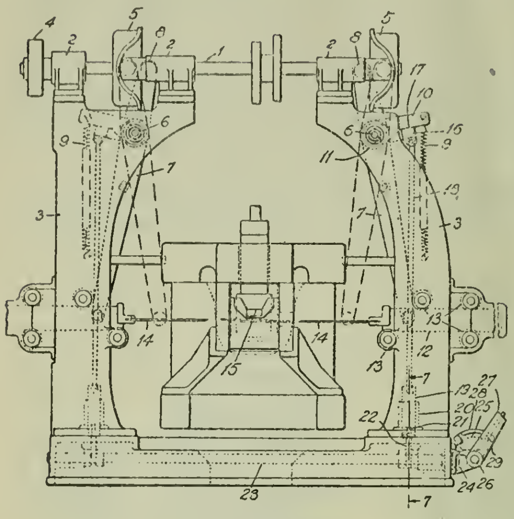


Fig. 99.

In the type of machine shown in Fig. 99 a horizontal shaft, 1, carries two cam-wheels, 5. In conjunction with these are two shear levers, 7, turning on studs, 6. The upper end of each lever carries a roll, 8, which is kept in contact with the cams, 5, by means of the springs, 9, connected to the arm, 10. The lower end of each lever is connected with a horizontal movable slide, 12, to which is attached a shear blade, 14. Thus as the shaft, 1, is driven, the shear blades move towards and from each other at the proper intervals.

The levers for reciprocating the shear blades are thrown out of action by a stop arm, 16, mounted on the same stud as the lever and operated by the rod, 18, which in turn is raised by a hand lever, 27, actuating the cam, 22, through the bevel gears, 24 and 25. When the arm, 16, is raised it holds the upper ends of the levers, 7, inward, so that their rolls, 8, are kept clear of the cams, 5. When the levers are released they commence cutting operations again in synchronisation with the rest of the machine. S. E.

158. Glass Feeding Device. O. M. Tucker and W. A. Reeves, Columbus, Ohio, U.S.A. (Brit. Pat. No. **131586**, August 5th, 1919, No. 19288).—In extruding charges from a discharge orifice, pressure is applied to the molten metal so that "the rate of extrusion is not less than the rate of downward travel of the already extruded glass." H. G. C.

159. Glass Working. F. L O. Wadsworth (Ball Bros.' Glass Manufacturing Co.) (U.S.A. Pat. No. **1323507**, December 2nd, 1919. Filed February 23rd, 1915, No. 9878).—This invention relates particularly to the severing of a stream of molten glass as it flows continuously from a tank, and the provision of a temporary support for, and the shaping of the cut end during the period of mould movement.

A hole, 3 (Fig. 100), is provided in the floor of the flow block chamber, and below it is fixed a flow ring, 4. The amount of metal flowing through this ring is controlled by the movable plug, 5, the temperature of the ring itself, which can be varied by circulating water round the flow ring plate, 6, and by the temperature maintained in the flow block chamber. The shearing mechanism consists of two blades, 7 and 8, which are fixed obliquely and so shaped that when the stream of glass has been cut the upper cut end rests in a shallow V formed where the two blades meet. Immediately after the stream of glass has been severed the two support blocks of a bad conducting material are brought together, and the glass is allowed to accumulate in the pocket, 47. This supporting cavity can be heated electrically by heaters as indicated at 48, and thus the glass can be made to remain so soft as to obliterate any shear marks. A further advantage of collecting the glass is that by using a suitably shaped pocket the molten metal can be made to assume the shape of the mould into which it is to fall when the two halves of the support move apart. S. E.

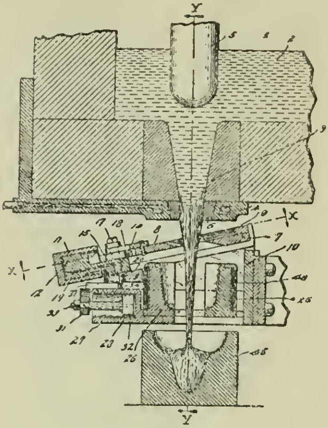


Fig. 100.

160. Glass Feeding Device. British Thomson-Houston Co., London, and J. Gray (Brit. Pat. No. **131756**, September 12th, 1918, No. 14862).—In a machine for manufacturing glassware, more especially bottles, lamp bulbs, etc., predetermined quantities of glass are discharged periodically from a tank or forehearth by a reciprocating displacer, 1 (Fig. 101), which is lowered into the tank to raise the level of the metal. The displacer is preferably of conical form, and is adjustably mounted so that its depth of immersion may be varied. Water may be supplied to keep the displacer moist during working. H. G. C.

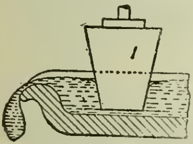


Fig. 101.

161. Apparatus for Feeding Molten Glass. W. A. Lorenz, Hartford Fairmond Co. (U.S.A. Pat. No. **1300181,** April 8th, 1919. Filed August 7th, 1917, No. 184875).—The gathers of glass flowing down a trough or conduit from a feeder are often not of a suitable shape to run direct into a mould on a machine table. If they are run in directly, they are liable to choke up the mouth of the mould, or to enclose large air bubbles which completely spoil the product. This is overcome by fixing a curved funnel, 17, over the mouth of the mould 14 (Fig. 102) in line with the conduit. The curvature of the funnel is such that the axis of the discharge end is in line with the axis of the mouth of the mould, while the axis of the open end is in line with the conduit. The delivery end of the funnel is substantially the same shape as the cross section of the mould, and always slightly less in diameter, so that the glass in passing through the funnel is shaped, and then falls freely to the bottom of the mould. Sometimes for round moulds the delivery end of the funnel is elliptical, so that glass which is generally shot into it more or less flattened is only partially shaped. It is claimed that such an oval mass of glass falling into a mould allows of the freer displacement of the air from the mould. S. E.

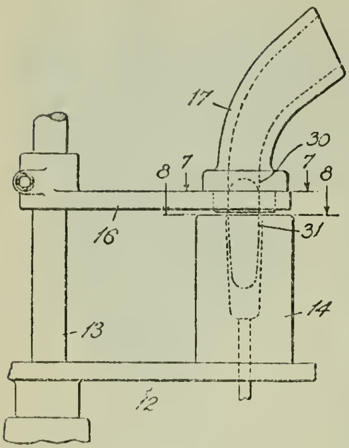


FIG. 102.

162. Gathering by Suction. EMILE ROIRANT (U.S.A. Pat., July 29th, 1919, No. **1311249**. Filed November 14th, 1918, No. 262591).—In gathering metal by suction, the introduction of the lower portion of the mould into the metal has the effect of chilling the metal, so that after several successive gatherings at the same place, the glass can no longer be used. In order to avoid this disadvantage, a block, 1 (Fig. 103), having an aperture, 4, is floated on the metal, 2, beneath the mould. Thus, when the mould is lowered, it makes contact with the block and depresses it in the metal, so that the charge is sucked into the mould through the aperture, 4. As the surface of the mould does not come into contact with the mass of metal, the obstruction caused by chilling of the metal is avoided. G. D.

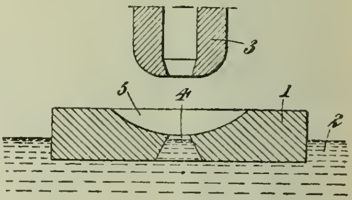


FIG. 103.

163. Automatic Glass Feeder. S. D. OLSEN, Leeds (Brit. Pat. No. **132898**, October 3rd, 1918, No. 16089).—Relates to an automatic feed for machines for making glassware, and consists in receiving the stream of metal in a water-cooled cup, which can be turned over to deliver the charge of metal into an inverted parison mould. Thus, the hottest portion of the charge is delivered into the lower, or neck, portion of the parison mould. The cup, *a* (Fig. 104), receives the metal from the tank extension, *b*, the supply being cut off at intervals by a blade, *c*. The blade works in conjunction with a small auxiliary cup, *n*, in which the metal collects while the cup, *a*, is being inverted. The cup, *a*, is water-jacketed, the inner lining which makes contact with the glass being made of carbon, cast iron, etc. The cup is mounted on a shaft, *o*, which is turned through a half-circle by a rack, *d*, attached to a piston in a cylinder, d', to bring the cup into the position shown in dotted lines, so as to deliver the charge of metal into the parison mould, *f*. The piston is operated by compressed air or steam, and is controlled by a valve, the rod, *i*, of which is connected to an arm, *k*, actuated by the machine for making the ware. A finger, *h*, is fitted to the outer end of the rod, *k*, and, when the rod is lifted in order to cause the inversion of the cup, *a*, the finger trips a latch, *l*, and allows the blade, *c*, to be closed by a spring. The latch, *l*, is pivoted to the upper end of an arm, *p*, which is rotatable in the shaft, *o*. A stop on the shaft, *o*, alternately makes contact with shoulders on the arm, *p*, so that the arm is moved backwards to bring the latch behind the blade, *c*, and then moves the blade to permit a resumption of the flow of metal when the cup is again in the filling position. H. G. C.

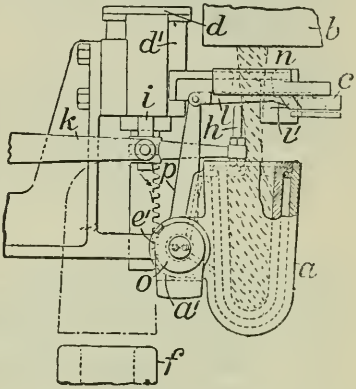


Fig. 104.

164. Grinding Glass Stoppers. M. Mathy, Belgium (Brit. Pat. No. **131547**, February 17th, 1919, No. 3900).—Relates to apparatus for grinding glass stoppers against the necks of the bottles they are to fit. As shown, the stopper, 10 (Fig. 105), is held in a rotating carrier, 7, by means of an indiarubber or like elastic block, 8, the edges, 11, of which overlap the bulge of the stopper so as to grip it securely, but resiliently. The bottle, 12, is applied to the rotating stopper by hand. H. G. C.

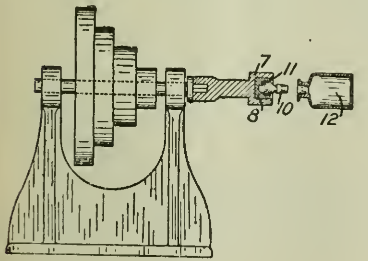


Fig. 105.

165. Glass Delivering Apparatus. EMILE ROIRANT (U.S.A. Pat., June 17th, 1919, No. **1307150**. Filed August 13th, 1918, No. 249706).—The invention consists of a device for collecting molten glass from a furnace and delivering it to a gathering device arranged at some distance from the furnace. It consists of a receiver, 11, which swings between the two positions shown, and can thus receive metal from a spout, 13, and convey it to a machine. The spout is closed by a gate, 14, which can be lifted by the receiver as it comes beneath the spout. In order to keep the metal in the receiver hot, an electric current can be passed between two electrodes, 23, since the hot metal is a conductor, and thus maintain the temperature. G. D.

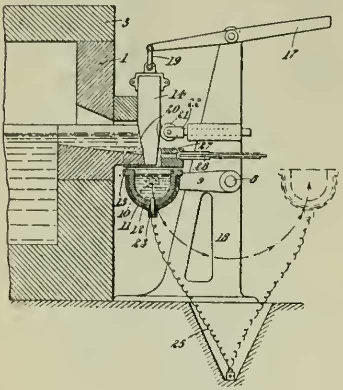


FIG. 106.

166. Glass Delivery Apparatus. F. L. O. WADSWORTH (Ball Bros.' Glass Manufacturing Co.) (U.S.A. Pat. No. **1307527**, June 24th, 1919. Filed July 30th., 1914, No. 854024).—The object of this invention is to deliver in an upward direction a constant stream of molten glass under a gravity head, and in such a condition that open-bottomed receptacles may be brought into register with the delivery orifice and filled.

The chamber, 2 (Fig. 107), which is built on to the working end of a tank furnace, is provided with a downward outlet, 4, which is surrounded by a furnace, and terminates in an

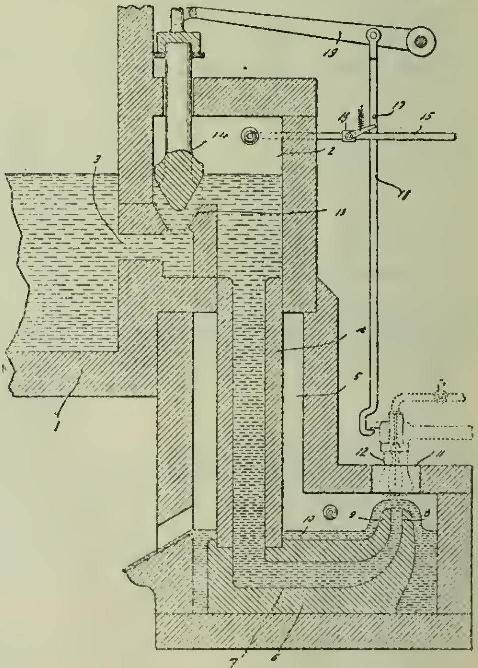


FIG. 107.

upwardly directed nozzle, 9. Immediately above the nozzle is an opening, 11, in the wall of the furnace, through which moulds or other receptacles can be lowered. If desired, a valve, 14, may be interposed between the furnace and the chamber, 2, so as to regulate the flow of glass. In cases where the pressure due to the head of molten glass is insufficient it may be supplemented by air or gas pressure through the pipe, 15, in which case the valve, 16, and the glass regulator, 4, may be operated simultaneously through the rod, 18, when the moulds are lowered into position. S. E.

167. Glass Discharging Mechanism. J. Rau (U.S.A. Pat. February 3rd, 1920, No. **1329851**. Filed September 10th, 1918, No. 253363).—In this method of discharging molten glass, a spout structure is built on to the working end of a tank as shown in section in Fig. 108. Across this spout structure is built a wall, 13, which has an opening, 14, into a plunger chamber. This plunger chamber is circular, and communicates with a delivery chamber through the orifice, 17. A circular plunger, 18, operates vertically in the chamber, so that in its downward stroke it closes the connection, 14, to the main tank and then forces molten glass through the passage, 17, and over the lip, 22. This lip projects outwardly so that it overhangs and stands out beyond the lower part of the front wall of the discharge chamber, thus the molten glass falls clear of the walls as it flows over the lip.

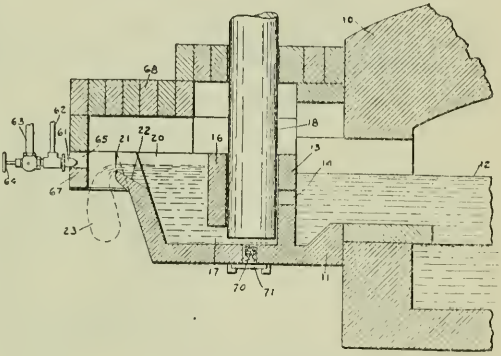


Fig. 108.

When the plunger is raised, the level of the glass in the chamber, 20, immediately falls and helps to sever the glass at the point, 21. This separation is assisted by a hot blast from the burner, 61, which not only facilitates the separation of the globule of glass, 23, but also cleans the lip by preventing the formation of threads of glass. The amount of glass forced over the lip can be varied by altering the length of the stroke of the plunger. S. E.

168. Mould for Glassware. K. E. Peiler and W. A. Lorenz (Hartford Fairmont Co.) (U.S.A. Pat. No. **1331471**, February 25th, 1920. Filed March 26th, 1915, No. 17181).—This invention relates to a sectional mould, the improvements enabling the mould to be opened or closed, locked or unlocked all by one hand of the operator, leaving his other hand free to remove the glassware.

Fig. 109 shows a plan view of an embodiment of the invention, showing the two halves of the mould in the open position. The mould sections 7 and 8 are hinged on a stud, 6, which is secured to the base plate, 5. The closing movements of the mould sections are controlled and made substantially equal by the links 22 and 23, which are connected to the mould sections by means of the studs, 25, and to the swinging arm, 10, by means of the stud 24.

The operating handle, 30, is hinged on a stud, 31, carried by a lug, 32, on either of the sections, in this case on section 7. This handle serves the double function of opening and closing the mould sections, and of clamping them together in the closed position. For its clamping function, the handle is provided with arms, 34, having bevelled inner faces, which engage the opposite outer sides of the lugs, 35 and 36, projecting from the mould sections. A suitable amount of end play of the handle on its hinge stud, 31, is allowed to permit the mould sections to centre themselves round the basepiece, 11, without any undue strain. Fig. 110 is a side elevation partly in section taken through the longitudinal centre of the apparatus when the sections are in their closed position. S. E.

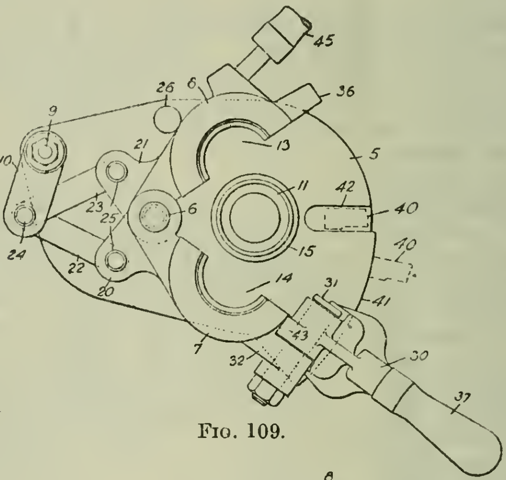


FIG. 109.

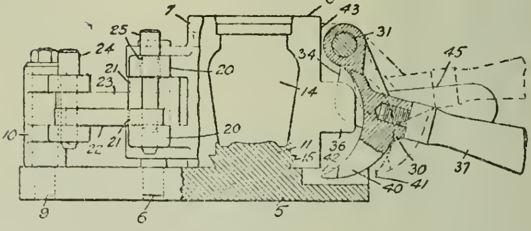


FIG. 110.

169. Cleaning off Machine. A. A. KRIDER (U.S.A. Pat. No. **1329841**, February 3rd, 1920. Filed November 30th, 1918, No. 264877). — This machine consists of a double chain conveyor which carries used blowpipes along in front of and at right angles to a cleaning rotor, which has cutting blades for removing the unused glass from the ends of the irons.

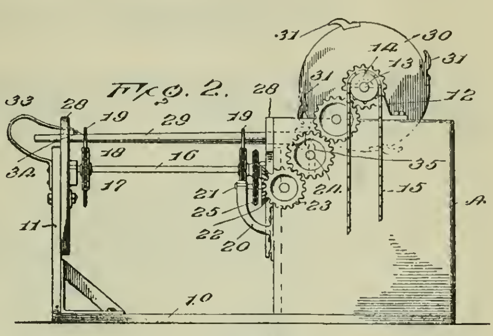


FIG. 111.

In Fig. 111 *A* is a box adapted to receive broken off glass and has its base, 10, extended on one side, and this, in turn, carries the upright wall, 11. Between this wall, 11, and the side of the box are two shafts, 16, carrying four gear-wheels, 17, over which pass two conveyor chains, 18, each chain being fitted at intervals with hooks for engaging with and carrying along the blowpipes, 29, which are placed across these conveyor chains.

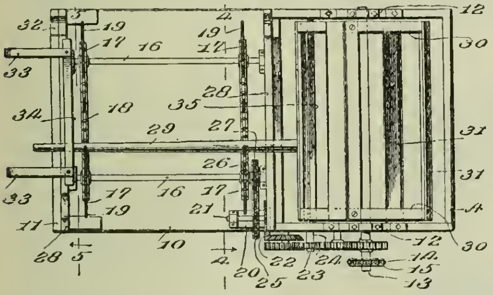


FIG. 112.

Mounted above the box is a shaft, 13, which carries two discs, 30, to which are secured at intervals striker blades, 31. These blades, when in action, strike against the ends of the blowpipes supported on the chains, and remove any adhering glass.

Fitted to the wall, 11, is a retaining rail, 34, above the outer chain, which serves to prevent any upward swinging of the outer ends of the irons when they are struck by the blades, 31.

The conveyor chains are driven from the main shaft, 13, by a train of gear wheels and two bevelled gear wheels, 22 and 23.

S. E.

X.—Glassware Accessories.

170. Machine for Washing Bottles. A. J. PETERSEN Dortmund, Germany (Brit. Pat. No. **133976**, May 4th, 1918, No. 7533).—Relates to apparatus of the endless-chain conveyor type, wherein the charging and the delivery of the bottles take place at the same end, the holders being opened and closed automatically. According to the invention, the charging is effected on one side of the conveyer and the delivery on the opposite side thereof. The dirty bottles are fed by a horizontal conveyor, *a* (Fig. 113), to a point where the operator at *b* can place them base downwards in the holders. After passing through the tank, *d*, they are sprayed by jets, *j*, and then passed through rinsing-tanks, *g*, *h*, *i*, and over a draining tray, *k*, to an automatic releasing device at *l*, where they slide on to a conveyer, *m*, ready for being placed on to a brushing and syringing machine, *u*, on the side of the conveyer opposite to the charging point. The bottle-holders, *c* (Figs. 114 and 115), are furnished with spring-hinged bottoms, 7, which are held by latches, 11, the outer ends of which are formed with extensions, 12, moving in the path of a releasing stop, 13. Forked holders, 16, embracing the bottle necks, are freed by their ends, 17, coming into contact with a cam guide, 19. In a modified arrangement, the holders are emptied on the outer and filled on the inner side of the chains. H. G. C.

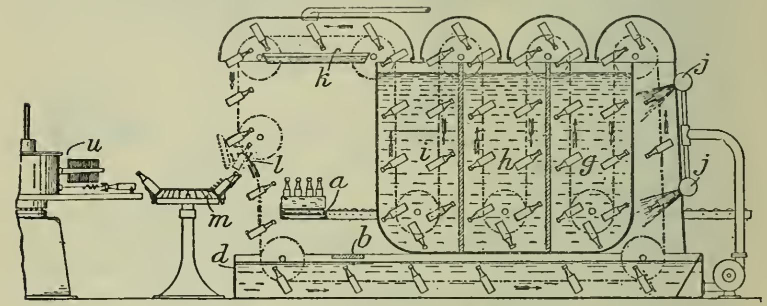


FIG. 113.

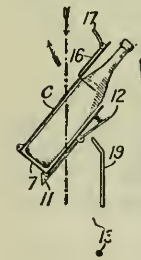


FIG. 114.

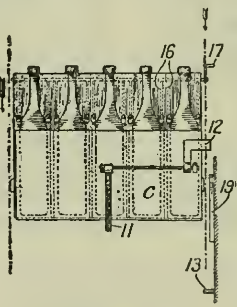


FIG. 115.

I.—Glass-making Materials.

171. Points to be Regarded in Changing Supplies of Potash or Soda. L. Springer (*Sprechsaal*, 1919, 52, 362).—Difficulties had frequently arisen in the glass industry through the substitution of one brand of soda or potash for another. The author discussed the source of and remedy for these irregularities.

A. *Potash*.—The chief sources of potash for the glass industry were: (i) From molasses, a by-product of the beet-sugar industry containing approximately 80—85 per cent. of K_2CO_3, 7—15 per cent. of Na_2CO_3, 4—7 per cent. of K_2SO_4, and 3—4 per cent. of KCl. By further purification a 95 per cent. potash could be obtained from this, containing the other constituents in correspondingly smaller amounts.

(ii) Calcined mineral potash from the Stassfurth salt beds, containing 97—99 per cent. of K_2CO_3, 0·05—1·25 per cent. of KCl, and traces only of other salts.

(iii) Hydrated or crystal potash, very pure and containing little chloride, but including 17·4 per cent. of water and only 80—83 per cent. of K_2CO_3.

(iv) Occasional supplies from wood ashes, approximating in composition to (i).

The larger the amount of soda ash (Na_2CO_3) present, the more readily did the potash and glasses made from it melt, but such potash was unsuitable for the manufacture of pure potash glasses.

Alkaline chlorides were useless as sources of alkali, but had a beneficial effect on the plaining of the glass, as they volatilised at high temperatures.

Alkaline sulphates in small proportion were not deleterious, but if in excess gave rise to "glass gall."

Particular regard should be paid to the water content, as potash was very hygroscopic, and in ascertaining the moisture care should be taken to ensure that a representative sample was used. (The author mentioned a sample which showed 5·8 per cent. of moisture on the fine-sieved powder and 21·5 per cent. on the lumps in the same sample.)

The substitution of a high-grade potash (type ii) for a lower-grade one (type i) in the manufacture of a potash glass, such as Bohemian crystal, caused the glass to melt with greater difficulty, to plain more slowly, and frequently to contain a fine seed. The addition to the batch of 3 parts of common salt or 2 parts of salt-cake per 100 parts of sand caused the metal to plain readily, though pots with the same batch and in the same furnace, but without the addition of the salt, remained seedy.

Even with the addition of the salt the glass made from the higher grade potash took longer to found, and was harder than when the lower grade material was used. When the actual amount of K_2CO_3 in the lower grade material was calculated and the amount of the higher grade potash in the batch reduced to correspond, with a simultaneous addition of soda-ash to make the composition of the batches the same, the results obtained were quite satisfactory.

If hydrated potash were used, an extra quantity should be added to introduce the same amount of K_2CO_3, on account of the large moisture content.

Potash glasses entirely without soda could be made successfully, but a higher furnace temperature was required.

B. *Soda.*—Leblanc soda-ash, which frequently contained considerable amounts of chloride and sulphate, had now been superseded almost entirely by Solvay- or ammonia-soda, which was usually fairly pure and contained 97—99 per cent. of Na_2CO_3, 0·3—2·0 per cent. of NaCl, and traces only of sulphate.

The chief difference in soda-ash samples consisted in the volume weight of the material, which might be either "light" or "heavy" soda.* Heavy soda was usually preferred, on account of its steadier melting in the furnace and less liability to excessive foaming, though both types were equally pure.

The moisture content of the soda-ash required control, particularly if kept long in storage. (The author quoted an instance of a sample of soda-ash containing 5 per cent. of moisture when delivered and 48·5 per cent. after lying in stock a considerable time.)

Soda-ash that had gone "lumpy" through storage required particular care in the ascertaining of the moisture content.

Some manufacturers made a brand of soda-ash containing 8—10 per cent. of salt-cake, and it was claimed that this gave good results in the glass industry, resulting in a glass that melted more readily and founded more rapidly than when pure alkali was used. The addition of a small quantity of salt-cake to a soda-ash batch was recommended, but if an excess was added it gave rise to difficulties with "glass gall."

In the production of a carbon amber, particular care was necessary to ensure that the batch contained a constant quantity of salt-cake. If the soda-ash used contained more sulphate than that previously in use, a much deeper amber tint would be obtained, and to ensure a constant colour either some salt-cake should be removed from the batch or the amount of added carbon be reduced. J. H. D.

172. Potassium Nitrate from the Chilean Nitrate Industry. P. F. Holstein (*J. Ind. Eng. Chem.*, 1920, **12**, 290).—This paper presented some of the main facts of the situation and briefly described the means actually at hand by which potash might be recovered. The author stated that even should the price of potash drop to the pre-war leved, a substantial profit would still remain to the nitrate manufacturers.

The potash nitrate was separated from the mother liquor resulting from the treatment of the "caliche," or crude nitrate ore. The composition of the hot concentrated liquor that was run from the boiling tanks to the crystallising pans varied, and many other salts, such as sulphates, borates, iodates, perchlorates, etc., might be in solution. For ores containing a fairly high percentage of potash (5 per cent. calculated as potassium nitrate) fractional crystallisation would give a commercially profitable potassium nitrate at an insignificant cost above that of the regular nitrate. When the liquor had reached the proper temperature in the crystallising pans it was transferred to other pans, where it cooled to air temperature, this second deposit being the high potash nitrate.

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* This Journal, 1917, **1**, *A* 4.

A solution containing a higher percentage of potassium nitrate might be obtained by evaporation of the mother liquor. In this case, care should be taken to regulate the time of standing in the crystallising pans, otherwise the nitrate would be rather high in sulphate and magnesium, and consequently in moisture.

Refrigeration of the mother liquor had yielded good results on some plants. The process was based upon the fact that the mother liquor was saturated with potassium nitrate at the temperature of the air, and that at lower temperatures the solubility of potassium nitrate decreased more rapidly than the solubility of sodium nitrate. By adding a small quantity of water to the mother liquor before refrigeration, a nitrate much higher in potash resulted in a single operation. A great economy was thus involved should the nitrate be subsequently refined.

Refrigeration would produce a higher grade nitrate at a much lower cost than evaporation, but if properly carried out evaporation had the advantage that the water removed from the system might be used as an additional wash water for washing the tailings in the boiling tanks, thus increasing the recovery of sodium nitrate.

C. M. M.

173. Solidification Points of Mixtures of Metallic Chlorides. Part I. Mixtures of Sodium, Potassium, and Calcium Chlorides. Fred C. A. H. Lantsberry and R. A. Page (*J. Soc. Chem. Ind.*, 1920, **39**, 37T).—NaCl–KCl *Series.*—These two components apparently formed a continuous series of solid solutions, for none of the cooling curves showed any arrest point after solidification was complete, which indicated the absence of a eutectic. The lowest melting mixture contained 55 per cent. of KCl and 45 per cent. of NaCl, and solidified at 650°.

$CaCl_2$–NaCl *Series.*—Again, no eutectic point was observed in any melt, hence it would appear that these two components formed a continuous series of solid solutions. It was found that when sodium chloride was added to calcium chloride, the freezing point was lowered considerably. The lowest melting mixture contained 72·5 per cent. of $CaCl_2$ and 27·5 per cent. of NaCl, and gave a freezing point of 505°.

$CaCl_2$–KCl *Series.*—This series proved quite different from the two previous systems. Two eutectic points were most marked, while the liquidus reached a maximum at 725°, the mixture then containing about 70 per cent. of $CaCl_2$. This corresponded to the formation of a double compound, $2KCl,3CaCl_2$.

The $CaCl_2$ compound eutectic melted at 608° and contained 17·5 per cent. of KCl, while the KCl compound eutectic had a melting point of 590° and contained 60 per cent. of KCl.

Ternary Series, $KCl–NaCl–CaCl_2$.—In this system two ternary eutectics were formed, one containing 70 per cent. of $CaCl_2$, 25 per cent. of NaCl, and 5 per cent. of KCl, and the other consisting of 30 per cent. of $CaCl_2$, 20 per cent. of NaCl, and 50 per cent. of KCl. The former, which was the lowest freezing mixture of the whole series, began to freeze at 495°, while the latter mixture began to freeze at 530°.

The paper contained many interesting and instructive tables and diagrams. C. M. M.

II.—Glass: Manufacture and Properties.

174. Laminated Glass. M. W. Gleason (Assignor to Gleason Tiebout Glass Co., New York) (U.S.A. Pat., June 1st, 1920, No. **1342282**. Filed June 10th, 1919).—This invention relates to the formation of laminated glass, the various laminations being so chosen that when the compound glass is used as an electric lamp globe, it produces a light very similar to natural daylight. In Fig. 116, which is an enlarged section of such a compound glass, the innermost layer, 10, is relatively thin and of a distinct tint, such as blue, though being so thin and its colour relatively mild, it does not materially alter the appearance of the whole glass, but merely modifies the light passing through it. The intermediate layer, 12, which is approximately of the same thickness as the layer 10, is a white opal glass. The outermost layer, 11, is clear and colourless, and is materially thicker than the other two. The molten glass from which the several laminæ are formed is assembled by the blower dipping his pipe first into the blue, then into the opal, and lastly into the clear glass. S. E.

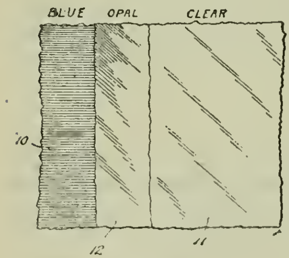


Fig. 116.

175. Reinforced Glass and a Process for Making It. Léon F. Mascart (France) (Assignor to Société du Verre Triplex, Paris, France) (U.S.A. Pat., June 1st, 1920, No. **1342267**. Filed March 21st, 1914).—In the manufacture of non-shatterable glass by means of a core of celluloid, it was of importance to be able to use naturally hard or hardened gelatine to glue the sheets together.

In order to carry out this invention, two sheets of glass were each covered with a layer of gelatine in the ordinary way, and then a solution of nitrocellulose or celluloid was spread evenly over them and allowed to dry. The layer of celluloid thus obtained adhered strongly to the gelatine, but to ensure satisfactory adhesion in every case, it was necessary to add to the celluloid solution a small proportion of various substances which were solvents for both gelatine and celluloid, for example, acetic acid and formamide. For completing the manufacture, these prepared sheets were dipped into alcohol (90 per cent.), and after being exposed to a temperature of 60—70° were pressed against one another, or on to a sheet of celluloid or other cellulose ester which had been inserted between them. The process might be shortened by dipping the sheets of glass covered with gelatine films into alcohol containing one of the common solvents for gelatine and celluloid. It was then sufficient to press the sheets of glass against a core of celluloid inserted between them, the temperature conditions above referred to being observed.

Another improvement which contributed to the increased adhesive power of a celluloid sheet to a gelatine film consisted in mechanically or chemically treating the celluloid sheet. (See Abs. No. 176.) S. E.

176. Manufacture of Reinforced Glass. LÉON F. MASCART (France) (Assignor to Société du Verre Triplex, Paris, France) (U.S.A. Pat., June 1st, 1920, No. **1342268**. Original application filed March 21st, 1914, No. 826/411. Divided and this application filed September 12th, 1918).—The adhesion of a sheet of celluloid to a layer of hardened gelatine or a sheet of glass might be strengthened by slightly roughening the surface of the celluloid. This might be done by a sand blast or by treatment with a reducing agent, for example, an alkaline sulphide or any of the agents for denitrating nitrocellulose. The celluloid with its surface thus treated adhered to a sheet of gelatine if the two sheets were dipped into alcohol and pressed against one another while warm. The same results might be obtained by dipping a treated sheet of celluloid into a hot solution of gelatine and letting the gelatine dry on it. The compound sheet might then be dipped into alcohol and pressed between two sheets of glass, either uncoated or coated with gelatine. S. E.

177. Making "Safety" Sheet Glass. C. SHUMAN and V. SHUMAN (Assignors to the Super-Glass Co.) (U.S.A. Pat., December 9th, 1919, No. **1324361**. Filed April 20th, 1916, No. 92355).—The invention related to the manufacture of reinforced or splinterless glass in which a sheet of celluloid was secured between two thin sheets of glass, thus forming a compound sheet which did not splinter when cracked.

The process, which was designed to avoid the use of cements or solvents for securing the sheets, consisted in assembling two sheets of glass (with or without dry coatings of celluloid) on each side of a sheet of celluloid, subjecting the assembled sheets to pressure, then raising the temperature of the sheets to about 230° F. to soften the celluloid, next applying a higher pressure, and after maintaining the heat and pressure for predetermined time, finally lowering the temperature and releasing the pressure.

Apparatus for carrying out the process was described in detail and illustrated in the specification. G. D.

178. The Character of Plate Glass Surfaces. I. Makazawa and others (*J. Tokyo Chem. Soc.*, 1920, **40**, 422, 521).—The authors investigated the cause of the well-known "cloudy patches" which are frequently present on the surface of mirrors. Photomicrographs of these patches were obtained, and revealed a microscopic network, which also characterised those portions of plain plate glass which afterwards produced cloudiness in mirrors. This network was only visible in reflected light, though bright particles on a dark field could be observed when the glass was viewed obliquely by transmitted light. These bright spots were not due to dust or moisture, because they were present below as well as on the surface. The better the glass the more minute were the particles, and their size depended on the rate of annealing. This led the authors to suppose that they were granules formed at the time of solidification, and were of a crystalline nature.

J. R. C.

179. The Selection of Glass for the Manufacture of Ampullæ. G. E. Ewe (*J. Franklin Inst.*, 1920, **189**, 649).—The results were given of tests made on various types of glass tubing intended for the manufacture of ampullæ. The tubing should not yield alkali or spicules of glass during the process of sterilisation of pharmaceutical preparations. Neither a 1 per cent. solution of morphine sulphate nor a normal saline solution containing 0·2 per cent. of strychnine sulphate should become turbid when sterilised in ampullæ which had been thoroughly washed before use in dilute hydrochloric acid and water. The sterilisation of a 0·6 per cent. solution of sodium chloride should not produce any spicules of glass from the ampullæ used. F. W. H.

180. A Practical Test for the Resistance of Optical Glass to Weathering. F. R. von Bichowsky (*J. Amer. Cer., Soc.*, 1920, **3**, 296).—The author attempted to obtain a quick and trustworthy series of tests which would be varied enough to ensure that no possible fault in the glass as regards resistance towards climatic conditions could be overlooked.

Spotting with 1 per cent. acetic acid solution and allowing the acid to evaporate was not a sufficiently sensitive test, whilst exposure to 1 per cent. acetic acid or glucose solutions gave ambiguous results; in any case, these tests occupied too much time.

The glass tested was obtained in the form of pressed or polished plates from 1 to 2 cm. in thickness. The first test recommended was a very slightly modified form of Mylius's iodeosin test. Three solutions were needed, and details of these were given, and also a detailed description of the method used. The amount of dye remaining on the fresh surface of the glass was estimated by dissolving it in a little water and comparing the colour with a standard made by using a solution containing 0·01 milligram of free iodeosin per cubic centimetre. The number of cubic centimetres of the standard solution needed to match the test colour multiplied by 100 and divided by the area, in square centimetres, of the surface tested, gave the number of milligrams of adsorbed iodeosin per square metre. The author termed this value the surface alkalinity constant of the particular glass. On the basis of this constant glasses could be grouped in five classes, as, for example:—

Class.		Milligrams per square metre.	Example.
1	Totally insoluble glasses	0—5	"Quartz glass" (fused silica).
2	Resistance glass............	5—10	Jena Geräte (chemical). Pyrex.
3	Hard glass	10—20	Flints, best crowns.
4	Soft glass	20—40	Ordinary crowns.
5	Poor glasses	over 40	—

Glasses high in lead, though very slightly soluble in water, gave high values in this test, possibly owing to the formation of a lead salt of iodeosin. Certain glasses containing barium and zinc gave low values, though they were highly soluble in acid. Hence the results of the surface alkali tests should always be considered, together with those of other tests.

For determining the rate of solubility of the glass in various agents several methods were tried and discarded. Finally, the glass was heated with the solutions in bomb tubes, and the surface appearances noted when wet and dry. The solutions used were water, 5 per cent. caustic soda, and 1:1 hydrochloric acid, no advantage being obtained by the use of other solutions. Half-inch cubes of glass were used and compared with a standard glass. For the water and alkali tests steel bombs were used, and for acid sealed tubes of Jena combustion glass. The tests in water and alkali were made at 225°, for four hours in the case of the former and two hours for the latter. The acid tests were made at 175° for six hours. The loss of weight of the cubes was also determined, but, owing to spalling and chipping, the loss in weight was scarcely as trustworthy as the appearance. The author graded the glasses as follows:—

Grade.	Appearance wet.	Appearance dry.
9	Thick slushy film.	Film more than 1·5 mm. thick.
8	Thick film.	Flakes off when dry.
7	Deep etching in scratches and corners.	Thin film, flakes off.
6	Deep etching in scratches and corners.	Thin film, does not flake off.
5	Opalescent film.	Deeply etched.
4	Opalescent film.	Not etched.
3	Film.	Film.
2	Clear.	Film.
1	Clear.	Clear.

Typical results were tabulated as under:—

Glass.	Surface alkalinity constant.	Solubility in water. Milligrams per centimetre cube.	Grade by appearance. H_2O.	NaOH.	HCl.
B.L. 100	44	130	6	7	2
B.L. 500	15	57	5	8	3
B.L. 3000	13	39	4	3	1
B.L. 3700	16	170? 54	1	2	1
B.L. 700	25	70	2	4	9
P.P.G. A.	24	420?	2	8	1
P.P.G. C.	33	86	4	2	2
P.P.G. E.	50	140	5	9	3
P.P.G. H.	18	51	3	5	1
Microscope flint .	39	—	1	2	1

Glass *B.L.* 700 lost one-tenth of its weight in boiling 1:1 hydrochloric acid in seventy-two hours, and in the six hours' test crystals of barium chloride separated out; otherwise it appeared to be a fairly good glass. Where all the tests indicated a poor glass, the author considered it likely that it would be unsatisfactory under actual weather conditions. Glasses giving results leading to different conclusions should be considered with suspicion until field data had been obtained.

In discussion, G. W. Morey considered that caution was necessary in considering tests made under such severe conditions as those indicated. Glass *B.L.* 700, for example, was found to give fair satisfaction in actual use, yet by one particular test it appeared very inferior. Tests were required to show the effect of changes of batch composition on a given glass, not merely the difference between various types of glasses, and if the method were long it would be worth while if the results were trustworthy. The effect of polishing on weathering as compared with that of a freshly-broken surface was also a question for investigation. F. W. H.

181. Note on the Mechanics of the "Weathering" of Glass. F. R. von Bichowsky (*J. Amer. Cer. Soc.*, 1920, **3**, 309).—The author advanced a theory of the mechanism of the action of water on glass. It appeared to progress through six stages. The true adsorption of water on the surface was followed by the diffusion of the adsorbed water into the body of the glass. This water then reacted with the glass and formed a surface film, which in turn soaked up water and induced further reaction. The soluble salts from the surface film, alkaline carbonates, and hydroxides formed a strongly alkaline solution which dissolved the silica skeleton film.

The heating of a glass which had merely adsorbed water on the surface resulted in a loss of weight corresponding to the amount of water adsorbed, but the surface of the glass remained unchanged. Glass at the second stage, when heated, showed a fine pattern of cracks, larger isolated cracks, and splinters. At the third stage signs of chemical change were usually present, such as a translucent skin, but no chemical change was observable in the first two cases. The skin, when dehydrated, became opalescent and chipped off. Varying results were, of course, obtained, depending on the composition, hardness, density, and tensile strength of the glass, and also on the length of time and rate of heating.

F. W. H.

182. Twenty-three Types of Optical Glass. R. J. Montgomery (*J. Amer. Cer. Soc.*, 1920, **3**, 404).—The author gave a general survey of the ordinary types of optical glass. Combining published information and practical experience, there were certain points emphasised. By plotting the figures for the dispersion and refractive index, the former along the horizontal axis, the glasses were found to fall into natural groups. They could be divided into twenty-three ordinary types according to composition, each type representing a group of glasses similar in optical properties, composition, and method of manufacture. The twenty-three types were as follows, numbers 2, 5, 7, 11, 12, 13, 14, 16, 19, 20, 21, and 22 being manufactured successfully on a commercial scale in America:—

1. Borosilicate crown.
2. Borosilicate crown, high n_D.
3. Crown of low n_D.
4. Light silicate crown.
5. Ordinary crown.
6. Telescope crown.
7. Ordinary crown, low n_D.
8. Soft silicate crown.
9. Zinc silicate crown.
10. Barium silicate crown.
11. Dense barium crown.
12. Densest barium crown.
13. Baryta light flint.
14. Baryta flint.
15. Dense baryta flint.
16. Telescope flint.
17. Extra light flint.
18. Borosilicate flint.
19. Ordinary light flint.
20. Ordinary flint.
21. Dense flint.
22. Extra dense flint.
23. Densest silica flint.

The glasses 16 to 23 showed the effect on the refractive index and dispersion of the increase of the lead content from 10 per cent. to 80 per cent., the refractive index varying from about 1·53 to 1·8, with a possible extension to 1·96, and the dispersion from about 57 to 33, with a possible extension to 19·7. Other lead-containing glasses, also containing barium and zinc, were illustrated by the dense baryta flint with about 10 per cent. of barium and 5 per cent. of zinc, the baryta flint and the baryta light flint containing 15 per cent. of barium and 10 per cent. of zinc. Glasses with lower refractive index were the borosilicate flint and an extra light flint where boric acid was used in place of barium. The telescope flint contained the smallest percentage of lead.

Of the glasses containing no lead, the first noted was the barium silicate crown with about 20 per cent. of barium, 10 per cent. of zinc, and 2 to 3 per cent. of boric oxide. The barium and boric oxide increased as the index increased from 1·54 to 1·61 through the dense barium crown to the densest barium crown containing about 40 per cent. of barium and 10 to 15 per cent. of boric oxide. The zinc decreased slightly with the high index values. Alumina, even up to 8 per cent., was often used in the densest barium glasses. The highest percentage of zinc was found in the baryta light flint and dense barium crown, reaching as high as 15 per cent. As the dispersion increased the percentage of zinc decreased, and was used in the zinc silicate and, to a small extent, about 2 per cent., in the soft silicate crown and ordinary crown with low index.

Soda-lime glasses were represented by the ordinary crowns, numbers 5 and 7, and the telescope crown, which also contained boric oxide and some barium.

Glasses containing boric oxide in larger amounts were the light silicate crown containing from 5 to 10 per cent., the borosilicate crown (No. 2), with about 10 per cent. and a rather high alkali, and the borosilicate crown (No. 1), with from 10 to 15 per cent., and which might also contain from 2 to 4 per cent. of barium or alumina.

For the development of new glasses the composition could be roughly determined by interpolation between known points in the particular field, as indicated in the plotted diagram previously mentioned. The diagram given included fields occupied by types of glasses with an index of from 1·45 to 1·8 and dispersion value of from 20 to 70. Borate and phosphate glasses, not containing silica, were not considered. F. W. H.

183. Optical Glass. W. Rosenhain (*Phot. J.*, 1911, **51**, 393).—Optical glass must be homogeneous, free from strain and colour, contain no "seed" or "stone," and show no sign of devitrification. Its hardness, durability, index of refraction, and dispersion must satisfy definite requirements according to its use.

In order to promote homogeneity, Guinand used a stirrer of the same fireclay as the melting pot, and this process was still employed. Striæ in glass could be detected as light or dark lines when examining the specimen in parallel light between two lenses.

Schott and Abbe's process of fine annealing, which retarded the rate of cooling from between 400° and 200° to 8—10° in twenty-four hours, eliminated strain from the glass.

Freedom from colour was obtained by the use of pure materials, not by the use of decolorisers, and no colour should be perceptible in a thickness of 12 inches. Flint glasses showed a yellow colour due to the lead content, but this was essential for the high refracting power of the glass, according to the Drude theory of refraction and dispersion.

Bubbles were likely to occur in optical glass, as the chemical composition was bound within narrow limits.

Usually, n_D, the index of refraction for sodium light and the "mean dispersion," that is, the difference between the indices of refraction, n_C and n_F, for the red and green lines of the hydrogen spectrum, were the only optical constants measured, but in some cases partial and relative partial dispersions were determined.

Abbe and Schott showed that the increase in dispersive power with refractive index, as is the case with ordinary flint and crown glasses, did not hold if boric oxide and barium oxide were also constituents of a glass.

The constants of minerals lay between much wider limits than those of optical glass; for instance, diamond had an index of refraction greater than 2, whereas the refractive index of optical glass lay between 1·56 and 1·7. Also, ν varied from 67—30 for glass, but for fluorite the value was 95. Hence minerals might replace optical glass as it was now produced. V. D.

184. Glass for *X*-Ray Tubes (*Times Eng. Suppl.*, December 27th, 1911).—A lithium glass was found to be about twice as transparent as soda glass to photographically active *X*-rays, and by using tubes provided with a lithium glass "window" 2 inches in diameter, the exposure necessary for radiographic work was reduced by half. V. D.

185. The Choice of Glass Batches containing Lime. W. E. S. Turner (*J. Amer. Cer. Soc.*, 1920, **3**, 379).—Dealing with the types of bottle batches containing sand, lime, and alkali, the author stated that batches with a high lime content, since the glass produced set quickly, were highly suitable for hand-working and for certain semi-automatic machines. For the modern, highly productive machines, a batch the composition of which might lie between 1000 sand, 412 soda ash, 166 limespar, and 1000 sand, 353 soda ash, 222 limespar, was generally found suitable, since a quick setting glass would render working difficult or even impossible when it came into contact with a mass of iron-work. Also, high lime glasses had a considerable tendency to devitrify, and would be liable to choke automatic-feeding devices. The glass with the lower lime content melted more quickly and was softer, rendering pressing and blowing easier and quicker.

Bottles and jars made from such glass could be left outside the lehr much longer than those made from a high lime glass, and hence were more suitable for automatic conveyors. The low lime glass was annealed at a lower temperature than the high lime glass, and therefore more quickly; it had a higher coefficient of expansion and a lower conductivity for heat. The higher conductivity of the high lime glass caused it to cool rapidly, and strains might be set up owing to the temperature of the articles falling below the annealing temperature before reaching the lehr. By preventing the entrance of draughts in the lehr, the possible trouble due to the higher coefficient of expansion of the low lime glass might be avoided.

As the lime content of the glass decreased so did the durability. The percentage of lime in the glass should not be less than about 7·5. F. W. H.

186. The Solubility of Boric Acid Frits. G. Blumenthal (*J. Amer. Cer. Soc.*, 1920, **3**, 152).—A number of commercial frits of unknown composition produced by sagger or furnace methods of melting were tested. Five grams of each, ground so as to pass a 20-mesh sieve but to be retained by one of 40-mesh, were placed in a glass cylinder with 350 c.c. of distilled water at room temperature and shaken for twenty-four hours in a shaking machine giving 17 revs. per min. Colloidal silicic acid separated out, and the water became more or less turbid after three or four hours. At the end of the shaking period the colloidal silicic acid was separated, dried at 110°, and weighed; the dissolved matter in 50 c.c. of the water was also determined, and the undissolved frit dried and weighed as a check on the amount of that dissolved. Blank estimations were run on the glass cylinders alone. The results were given as follows:

No.	Kind of frit.	Appearance of frit.	Colloidal silicic acid. Per cent.	Portion of frit soluble in water. Per cent.	Appearance of solution after shaking.
1.	Frit kiln	Glassy and clean ...	2·2	0·3	Clear; little silicic acid.
2.	Sagger	Not thoroughly melted	5·1	1·7	Quite cloudy.
3.	Frit kiln	Glassy and well fused	2·5	0·2	Cloudy.
4.	Sagger	Poorly fused ...	27·2	24·6	Very cloudy; frit slaked.
5.	Sagger	Slightly opaque, clean	2·2	1·9	Quite clear.
6.	Sagger	Glassy, contained undissolved flint...	4·6	1·8	Cloudy.
7.	Sagger	Glassy and clean ...	2·2	1·1	Clear.
8.	Sagger	Well fused, hard, of smoky appearance	2·2	8·0	Clear.
9.	Frit kiln	Glassy, undissolved flint..................	2·2	0·5	Clear.

The results showed that all the frits were soluble in water to some extent, but furnace-melted frits were apparently the least soluble, probably owing to more complete fusion and greater homogeneity. Considered theoretically, there was no objection to a high boric acid content when the type of composition tended to produce insoluble borosilicates, of which "Pyrex" glass was an ideal example. F. W. H.

187. The Viscosity of Molten Borate Glasses. H. F. Staley (*Eighth Int. Cong. Appl. Chem.*, 1912, Sect. III, C, Orig. Comm., **5**, 127).—The relative viscosities of the molten glasses were measured by determining the time taken for an immersed body of definite weight and volume to fall through a known distance. The viscosity decreased at a decreasing rate with increase in temperature, and the rate was peculiar to the glass. Although the viscosities might vary considerably at a low temperature, the rates varied so much that at high temperatures the values converged towards what might be regarded as a minimum. Any mixture of boric oxide with the bases baryta, lime, or strontia had a lower viscosity, at any temperature, than the boric oxide alone. The homogeneous magnesia product of composition $0{\cdot}5MgO,1B_2O_3$ could not be obtained. In a series of boric oxide and baryta mixtures the viscosity decreased continuously with an increase in baryta, but was not proportional to the percentage molecular amount of baryta present up to the mixture $0{\cdot}5BaO,1B_2O_3$, and from this up to $2BaO,1B_2O_3$ the decrease in viscosity was nearly proportional to baryta content. Volatilisation of boric oxide during melting took place only with mixtures containing less than 0·5 of the formula weight of the base to 1 of B_2O_3.

There was no relation between melting-point curves and the lines representing temperatures of equal viscosity for a series of borates. These lines were straight and roughly parallel for mixtures containing more than $0{\cdot}5BaO$ to $1B_2O_3$, and parallel and parabolic when the baryta was less than 0·5. The viscosities of mixtures of boric oxide and $0{\cdot}5BaO,B_2O_3$ were below the added values of the viscosities of the constituents of the mixture; hence it might be assumed that dissociation took place to a considerable extent in one, or perhaps in both end-members of the series, and that boric oxide was a polymerised substance broken down into simpler molecules in the presence of the base. V. D.

188. Watch Glass Manufacture. (*Sprechsaal*, 1919, **52**, 277).—The author maintained that it was an easy matter for any glass manufacturer making crystal or half-crystal glass to take up the production of watch glasses as a special branch, no great expense for plant being necessary and no special training required by the glass-blower.

As suitable batches for such a purpose, the following were suggested :—

	I.	II.
Sand	100	100
Soda	10	8
Potash	25	26
Limespar	20	15
Barium carbonate	20	—
Red lead	—	14

The working method was simple. A spherical bulb of glass was blown, the size of the bulb depending upon the thickness and curvature of the glasses required. After cooling, these spheres were cut up into suitably sized sections by means of a diamond-cutter and a three-cornered file, and from these sections the individual glasses were cut out with a diamond-compass or other suitable cutting arrangement.

The edges of the glasses were smoothed and bevelled to the desired degree by means of a grinding-stone, and the glasses then sorted according to their diameter, thickness, and curvature.

J. H. D.

189. Glass for Transmission of Ultra-violet Rays Only. H. P. Gage and W. C. Taylor (Brit. Pat., November 20th, 1919, No. **127586**. Convention date, May 28th, 1918. Application date in U.K., May 28th, 1919, No. 13508).—This relates to a glass, made by the Corning, U.S.A., Glass Works, which has a high transmission factor for the ultra-violet rays while absorbing visible light. The patent covers the use of nickel oxide in proportions varying from 0·5 to 12 per cent. of the whole batch. If certain oxides are present in substantial proportions the desired results are not obtained to the fullest extent. These oxides are lime, magnesia, lead oxide, alumina, and boric oxide. Typical batches protected by the patent are as follows:—

	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	48	54·1	51	57·4
K_2O	15·3	17·4	—	—
Na_2O	—	—	10·6	12·1
BaO	24·7	28·0	26·4	30·0
NiO	12·0	0·5	12·0	0·5
SiO_2	53·0	60·0	60·0	68·0
K_2O	20·0	22·5	—	—
Na_2O	—	—	13·8	15·5
ZnO	15·0	17·0	14·2	16·0
NiO	12·0	0·5	12·0	0·5

A small amount of red radiation is transmitted by glasses coloured with nickel, and the best batch composition for the purpose required is stated to be:—

SiO_2	50·0 per cent.	BaO	25·0 per cent.
K_2O	16·0 ,,	NiO	9·0 ,,

One or two per cent. (preferably the former) of cupric oxide added to this batch will cut out the red, but will also decrease the transmission in the blue.

J. R. C.

190. A Colloidal Method for Increasing the Volume of Adhesive Water-glass. J. D. Malcolmson (*J. Ind. Eng. Chem.*, 1920, **12**, 174).—The author stated that the desirable properties of water-glass for use as an adhesive were, in general, a function of the viscosity, and he described a method of increasing, to the extent of 25 per cent., the volume of adhesive water-glass by the addition of urine without impairing the viscosity and other desirable properties of the adhesive. This method involved the practical application of certain phenomena of colloid chemistry, such as coagulation and peptisation. C. M. M.

III.—Lamp-worked and General Scientific Apparatus.

191. A Manometer for Vacuum Distillation. H. T. Clarke (*J. Amer. Chem. Soc.*, 1920, **42**, 786).—The author advocated the use of a hook-shaped trap (Fig. 117) to prevent access of air or moisture to the vacuous space owing to movements of the mercury during changes of pressure, and also to prevent the breaking of the sealed end of the tube by the impact of mercury when air was suddenly admitted into the apparatus. The trap prevented access of air to the vacuous space, and if the hook was made of capillary sufficiently fine the movement of the mercury was retarded. F. W. H.

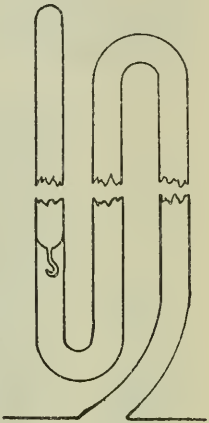


Fig. 117.

192. A Valve for Glass Apparatus. K. Bunge (*Chem. Zeitung*, 1920, **44**, 299).—A valve which could be used on burettes or on pipettes to prevent the entry of liquid into the operator's mouth was described. A glass tube, melted solid at one point, had on either side of the solid portion two small holes, the distance between the holes being not more than 1 centimetre. Over the valve was a piece of rubber tubing, and the valve could be operated by gentle pressure of thumb and finger. To mark the position of the valve a piece of coloured glass was used. F. W. H.

193. A Compensation Thermometer. H. F. Wiebe (*Zeitsch. Instrumentenkunde*, 1910, **30**, 245).—The author described a device to compensate for the change in the zero point of mercury thermometers. The thermometer was made of glass having a small thermal after-effect, a piece of glass having a large after-effect being placed in the bulb. The size of this piece, in order that the change may be eliminated, was calculated from the values of the after-effect in the two glasses. Thermometers so prepared were tested after many years and found to be satisfactory. J. R. C.

194. The Corrections for Enclosed Thermometers with Expansions in the Capillary. W. Meissner (*Zeitsch. Instrumentenkunde*, 1909, **29**, 93).—Six corrections were theoretically obtained, namely, (1) the correction when the thermometer was made of mercury and only one kind of glass; (2) the correction for different expansions of the bulb and the capillary; (3) for different expansions of scale and capillary; (4) for the scale being fixed at a point other than the zero; (5) the correction for the parts of the capillary which are widened; (6) correction for the error of the zero. The total correction was evaluated for thermometers made of glasses 59^{III} and 16^{III}. J. R. C.

195. Making Thermometers. F. J. BERBERICH (U.S.A. Pat., February 12th, 1918, No. **1255979**. Filed June 26th, 1917, No. 176953).—The invention consisted of a process of making insulated thermometers, shown in Fig. 119, in which the mercury was contained in a capillary tube, *a*, protected by an outer tube, the graduations being marked on a strip of paper or opal glass, which is inserted in the outer tube.

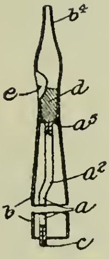


FIG. 118.

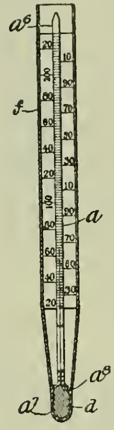
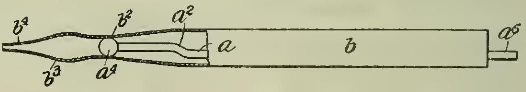


FIG. 119.

In the first part of the process, a small bulb, a^4 (Fig. 120), was blown on the end of the capillary tube, *a*, and an offset bend, a^2, was formed near the bulb. The tube, *a*, was then inserted in the outer tube, *b*, as shown, which was constricted at b^2, and drawn to a tapered point, b^4, the bulb, a^4, fitting snugly into the constriction, b^2. The tubes were then heated at this point, and the bulb, a^4, was burst, by blowing into the tube, *a*, so that it formed an open cylinder, a^5 (Fig. 121), which united with the walls of the tube, *b*, as shown. The open end of the tube, *a*, was closed temporarily, and a measured quantity of mercury, *d* (Fig. 118), poured into the part, a^5. A mark, *e*, was made on the outer tube to determine the point at which the bulb was to be closed. The mercury was then poured out and the tubes formed into the complete bulb, a^7 (Fig. 119). The final operation of filling the bulb and tube, *a*, with mercury was conducted in the usual manner. G. D.

FIG. 120.



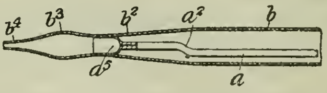


FIG. 121.

IV.—Decorated Glass.

196. Modern Art in the Glass Industry. O. PARKERT (*Diamant*, 1918, **40**, 16, 44).—The decoration of glass, according to the author, was undergoing a change similar to that taking place in all branches of art. The author made the same claims for the new generation of glass artists as were made for the modernist painters on canvas; he claimed for them originality instead of "uninspired imitation and continued copying." He believed that the modern glass decorators concerned themselves primarily with representing the spirit of that which they sought to portray and considered that, because of their originality and of the animation manifest in their designs, technical shortcomings could be overlooked. He was of the opinion that we were at present in a transition period comparable to that when the introduction of three-colour decoration of glass, by films of different coloured glasses on the article to be decorated, one or more of which films being removed to produce the desired design, was revolutionising glass window decoration, leading to the disappearance of the lead work in "stained glass" windows. The introduction of this process gave rise to the hand decoration of vases and similar articles by craftsmen who, proud of their skill, produced beautiful work. The impetus which the introduction of this process gave to glass decoration had, in the author's opinion, vanished, but the new spirit in art would effect as great an improvement in decoration as did that event. J. R. C.

197. Articles with Painting between Glass Walls. F. HUTH (*Diamant*, 1918, **40**, 100).—Two methods were described for producing hollow glassware with the painting embedded in the glass. In the first, the hollow article was blown, the decoration painted inside it, and then a layer of glass was blown inside, using the outer glass article as a mould. Hitherto the painting had been done with easily fusible coloured glass ground fine and mixed with turpentine or lavender oil. This was dried, and when the inside covering of hot glass came into contact with it, it melted and was "burnt in" between the two colourless glasses. This had the disadvantage that, when the inner glass had to be very hot to be workable, contact with the easily-fused glass paint sometimes caused the colours to run, spoiling the painting. A German patent had been granted for the employment of coloured oxides which have a melting point approximately the same as that of the superposed glass. This prevented premature melting of the paint, and the colours did not run. By suitably choosing the coloured oxide this mode of decoration could be used with glass of any composition, whereas hitherto it had practically been confined to lead glasses.

In the second method the decoration was painted on the outside of the first hollow article while it was still on the pipe. The painted glass was then dried, warmed, and dipped into molten glass, and by skilful blowing the whole was enlarged, care being taken that the painting was not distorted. In this method, of course, the easily-fused glass painters' flux could not be employed.

J. R. C.

198. The Firing of Painted Glass. F. Huth (*Diamant*, 1918, **40**, 43, 57).—Every mixture used for glass painting consisted essentially of a colouring substance and a fluxing agent, the latter effecting the combination of the former with the surface layer of glass during the firing process. These mixtures were divided into two classes: (1) those in which colouring oxides were mixed with the flux immediately before use, and (2) the so-called "glass-painters' fluxes," in which the oxide was already united with the fluxing medium to form a glassy body, this being pulverised and mixed with oil for application to the glass. In order to prevent the furnace gases from coming into contact with the painted glass, the object to be fired was enclosed in a muffle, and this was put inside the furnace. The muffle might be of iron or fireclay, iron muffles being used for colours which were to be fired at a relatively low temperature. The fireclay ensured a more uniform temperature throughout the interior of the muffle, and therefore was always used when great heat had to be applied. When the muffle was in the furnace, which might be heated by burning fuel inside it, the temperature was slowly increased, and the easily melted flux and the surface layer of glass combined and took up the colouring oxide. When this was accomplished the temperature must be very slowly lowered, or the glass would crack. In practice, test-pieces were put in the muffle with the decorated object, the furnace was run for about three days, and then the test-piece examined. If the firing was complete, the fuel was removed from the furnace, which was closed up and allowed to cool for a further three days before being opened. The firing might have to be repeated two or three times, in which case the second colouring mixture must contain more flux than the first. The repetition of the firing was a delicate process requiring careful handling. J. R. C.

199. Choice of Colours in Letter-painting. F. Huth (*Diamant*, 1918, **40**, 129).—A short note in which attention was directed to the attractiveness of coloured letters. Examples were given of possible combinations of colours, such as yellow letters on a blue ground and black letters on a gold ground. J. R. C.

V.—Optics and Optical Instruments.

200. Diffraction Patterns in the Presence of Spherical Aberration. (Mrs.) C. H. Griffiths (*Trans. Optical Soc.*, 1920, **21**, 87).—The paper described the appearances of the images, and of the expanded images, of an artificial star on each side of the focus of a telescope objective when there was a known difference of path between the margin and paraxial rays. With an objective free from spherical aberration the inside and outside focus appearances were almost the same. With an over-corrected objective the ring system outside the focus was clearer and better defined than that inside the focus, and the reverse was true for an under-corrected objective. The greater the aberration, the greater was the lack of symmetry. J. R. C.

201. A Projection Spectropolariscope. F. J. Cheshire (*Trans. Optical Soc.*, 1920, **21**, 102).—A polariscope specially adapted for class and lecture work was described. By placing the crystal under examination immediately against the slit from which the polarised light issued, a much sharper definition of the bands was obtained than was the case with the more usual apparatus.
J. R. C.

202. Spectrographic Objectives. R. Steinheil (*Zeitsch. Instrumentenkunde*, 1909, **29**, 256).—Three methods of forming these objectives with two lenses were given. The aberration was shown to be small when one of these methods was used. J. R. C.

203. The Construction of Optical Systems. H. Harting (*Zeitsch. Instrumentenkunde*, 1910, **30**, 359).—Dealt with two lens objectives. Formulæ were calculated for the construction of objectives of this type. J. R. C.

204. A New System of Correction Lenses. H. Boegehold (*Zeitsch. Instrumentenkunde*, 1910, **30**, 302).—If an objective be corrected for chromatic aberration for one pair of wave-lengths, it was possible to correct it for another pair by the addition of another lens system. The author developed the theory of such a system.
J. R. C.

205. The Aberration of Sloped Lenses and their Adaptation to Telescopes of Unequal Magnifying Power in Perpendicular Directions. Lord Rayleigh (*Proc. Roy. Soc.*, 1908, [*A*], **81**, 26).—The paper consisted of two parts. The first part treated of the general unsymmetrical aberration caused by sloping a lens, and showed how this may be minimised so as to become unimportant. In the second part the advantage which often attended a magnification unequal in different directions was discussed. It was found that a combination of a sloped object lens with a compound cylindrical eye-piece constituted a satisfactory solution of the problem. Formulæ were given from which the required obliquity might be calculated when the nature of the eye-piece and the focal length of the object lens were known.
J. R. C.

206. Homogeneity of Optical Glass. W. Zschokke (*Zeitsch. Instrumentenkunde*, 1909, **29**, 286).—The refractive indices of 199 specimens from the same melt were measured and found to vary from 1·61290 to 1·61490. A simple method of ascertaining whether or not a prism was homogeneous was described. The prism was laid on one side, and parallel light from an illuminated cross was incident on one of the other sides. It was refracted so as to be reflected from the horizontal side on to the third side, and, after refraction, viewed through a telescope of 25 magnification. If the prism was not homogeneous, the horizontal and vertical bars of the cross were not equally sharp. J. R. C.

207. Report of Standards Committee on Visual Sensitometry. (*J. Optical Soc. Amer.*, 1920, **4**, 55).—A preliminary report summarising the data at present available on (1) the visibility of radiation; (2) the intensity and contrast sensibility; (3) chromatic sensibility; (4) rates of adaptation; (5) absolute sensibility. Further reports were to be made annually. J. R. C.

208. The Surface Layer of an Optical Polishing Tool. J. W. French (*Trans. Optical Soc.*, 1920, **21**, 81).—The author suggested that in the later operating stage the surface layer of a pitch, wax, or kindred polishing tool was a continuous layer of glass. The primary action of the rouge was that of an abrasive; it removed the material, and thus lowered the surface to the bottom of the pits. The author described experiments which led him to suppose that the glass removed formed a layer of glass on the polisher, in which layer, however, as it was only a few wave-lengths thick, the irregularities of the surface of the polisher caused small islands of pitch to be present. Assuming the presence of this layer, the action of the polisher in the second stage was due to surface flow. In a discussion which followed the paper, experiments were detailed which appeared to indicate that this layer was not formed, or, if present, was not completely continuous, D. Taylor holding that the action of the polisher was a case of abrasive action carried to molecular dimensions. J. R. C.

VI.—Illumination and Illuminating Ware.

209. Colour Filters for Producing Artificial Daylight. M. Luckiesh and D. A. Dewey (U.S.A. Pat., February 24th, 1920, No. **1331937**. Filed August 21st, 1915, No. 46737. Renewed November 29th, 1919, No. 341469).—The invention related to colour filters or absorbing screens adapted to be used in conjunction with artificial light for the purpose of producing an approximation to daylight. The filters referred to are integral glass colour screens, and the following is an example of a batch which may be used to produce a glass suitable for use with a gas-filled electric lamp:—

Sand	1500 lb.	Arsenic	5 lb.
Soda	535 ,,	Manganese dioxide	3 ,,
Lime	160 ,,	Cupric oxide	5·66 ,,
Nitre	50 ,,	Black oxide of cobalt	0·26 ,,

This batch resulted in a glass which was blue in colour, but had a slight green tinge. If it was desired to approximate more closely to skylight, a purple glaze might be applied to the surface of the glass. Such a glaze might be composed as follows:—

Vitrifiable carmine (carmine No. 45)	50 grams.
Vitrifiable blue (blue No. 245)	2·5 ,,
Vitrifiable flux (flux No. 10)	30 ,,

The patent covered any blue glass to produce daylight effects containing copper, manganese, and cobalt. J. R. C.

VII.—Fuels, Refractories, and Furnaces.

210. Fuel and Producers. (*Sprechsaal*, 1919, **52**, 463).—The article dealt with points to be observed in attempting to reduce fuel consumption to a minimum and to obtain the best results from the fuel actually used.

Three systems had been used for heating glass furnaces, namely, direct firing from a grate, half-gas firing, and gas firing. Direct firing was very wasteful in regard to fuel consumption, and was now superseded. Half-gas firing required a better quality of fuel and was more wasteful than gas firing, so that gas firing was the only system to be considered.

For successful results the construction of the producers must be adapted to the work required, and they must receive adequate attention. Two points which called for attention were moisture in the fuel and the type of producer selected. Each kilo. of water in the fuel required 637 cals. to evaporate, and this heat was extracted from the gas. Further, if the fuel was very wet and the producers near the furnace, a large amount of steam was passed into the furnace with the producer gas, leading to pronounced cooling. If the producers were removed from the furnace, steam might condense in the gas mains.

For large-sized non-coking fuels, such as rough coal, briquettes, etc., shaft producers with flat grates were suitable if worked with a fairly deep fuel bed. Strongly coking coals were gasified more successfully in producers with sloping grates—either hanging or stepped grates.

Opinions varied regarding the most suitable size of producer, some preferring large and others small units. The author favoured the installation of three producers to each furnace, the size being such that in case of need the necessary gas could be produced from two of them whilst the third was under repair. Dimensions recommended by the author for single producers to gasify 8 tons of fuel in twenty-four hours were as follows:—

Shaft producers: 1·30 m. × 1·20 m. × 3·00 m. in width.

Step grate producers: 1·85 m. inside width, 2·00 m. depth, 3·00 m. outside height.

If only two producers were used and the capacity of these fully taxed to supply the necessary gas, shortage would occur periodically. If one of the producers were working sluggishly—say in consequence of a stoppage—the other would be driven more rapidly, would burn more fuel, but not produce the corresponding increase in the gas supply, so that a shortage of gas would result. Only by strenuous and repeated poking and cleaning out could the sluggish producer be restored to its normal action, and this would entail considerable waste in unburnt fuel. If one of these producers acted sluggishly, the other two were quickened, and the necessary amount of gas was available, so that the producer that was working badly could be brought back to a normal course gradually and without adopting drastic measures.

Intelligent working of and suitable attention to the producer were highly important in regulating fuel consumption. The depth of the fuel bed depended upon the nature of the fuel and upon whether the producer was working under natural or forced draught. The author recommended the following depths of fuel bed as suitable:—

	Under natural draught.	Under artificial draught.
Large coal	70 cm.	85 cm.
Bohemian lignite	60 ,,	70 ,,
Peat—compressed	80 ,,	95 ,,
Briquettes	85 ,,	120 ,,
Air-dry wood—20 cm. pieces	105 ,,	125 ,,

Under favourable draught conditions, for example, when the producers were at a low level and in the immediate vicinity of the furnace, the fuel bed should be rather deeper, and where the draught conditions were below normal the fuel bed could be rather shallower to reduce friction.

To regulate the height of the fuel bed and keep this constant the author recommended the provision of a cast-iron "filling shaft" reaching into the producer to the desired fuel level and supporting the usual feeding hopper at its upper end. As the fuel in the producer burned away and the level fell, fresh fuel dropped from the filling shaft, thus maintaining the fuel level in the producer. The shaft could be raised and lowered at will so as to regulate the height of the fuel level in the producer. J. H. D.

211. General Remarks on Glass-house Pots. (*Sprechsaal* 1919, **52**, 464).—The author mentioned briefly the chief points to be observed in the production of trustworthy glasshouse pots, such as careful selection and sorting of suitable clays, the correct amount of grog to be added, the necessity for careful preparation of the pot clay and its freedom from adventitious impurities, and careful heating up of the pot in the pot-arch. The pot clay should mature at least six weeks before use. Care should be taken that clay intended for pot-making did not get frozen, since if this took place the pots made from the clay were untrustworthy and corroded readily. Clay for pot-making should not be obtained in the winter months and should be stored in a frost-proof chamber.

The author discussed particularly the best strength to make the pots. This would naturally depend to some extent on the purpose for which the pots were required; thus for sheet glass much stronger and heavier pots were required than, say, for table ware. In general, however, a medium thickness was best, and extremes in either direction should be avoided. Very thick pots certainly withstood collapse through corrosion rather longer, but were more difficult to dry and heat up successfully without crizzles; the glass was more difficult to melt and plain in them, and consequently they were exposed for longer periods to the full heat of the furnace, and once the inner surface of the pot became badly corroded it was not suitable for good glass-making, since clay particles became detached from the surface, causing the glass to become cordy and stony. The idea that inferior grades of clay could be used for pot-making if the pot walls were made thicker was a mistaken one.

Pots should be built narrower at the bottom than the top. They were not so likely to bulge out under pressure of the molten glass at high temperatures, and also allowed the heat to get round them better, thus ensuring more uniform and regular founding of the glass.

Dimensions recommended were as follows:—

Pots for sheet glass: thickness of wall at the top, 8—10 cm. and at the bottom 12 cm. Bottom thickness, 13 cm.

Pots for table glass: thickness of bottom, 9 cm., the side walls tapering to 6 cm. at the top. J. H. D.

212. A Lining for Glass Pots. S. R. Scholes (*J. Amer. Cer. Soc.*, 1920, **3**, 498).—A process was described for the manufacture of glass pots making them less corrodible by molten glass, particularly a heavy lead–potash glass. An attempt was made to develop a lining on the pot wall which would protect it. A refractory clay body having the general character of porcelain was formed by using a mixture of 90 per cent. ordinary clay batch and 10 per cent. felspar. This mixture gave a dense body after burning at 1300°, and showed no sign of over-firing. The felspar formed a sintering bond between the clay particles, producing the phenomenon generally referred to as vitrification.

This lining was applied to the pot during building in the ordinary way, so as to give a finger course about half an inch thick up to the metal line, and continued 8 inches above that in gradually diminishing thickness. No difficulty was found in drying the pot, and a homogeneous body was always obtained. It was found that it was often necessary to reduce the proportion of felspar 5 per cent., depending on the temperature at which the pot was to be used. The lining was very dense, formation of stones was reduced to a minimum, and the useful life of the lined pot was from two to three times that of an ordinary pot in lead–potash melts. The lined pots were easier to handle than pots made entirely of the porcelain material, because the more porous structure in the raw condition enabled them to be heated in the pot-arch as rapidly as ordinary pots. The only difficulty experienced was the formation of cracks in the lining, owing to the sudden cooling of the dense material by the introduction of cold batch.

F. W. H.

213. Determination of the Strength of Stoneware Bodies and the Connection between the Values Obtained and the Composition and other Properties of these Bodies.

H. Harkort and A. Scherbius (*Sprechsaal*, 1919, **52**, 297, 309, 321).—The tensile strength of the bodies was determined by subjecting suitably shaped pieces of the body in question to gradually increasing tension until fracture took place. Preliminary experiments showed that it was difficult to get results in satisfactory agreement, owing to the difficulty in applying the tension directly down the middle axis of the test-pieces. By exercising great care in the formation of the test-pieces and the application of the weight, these difficulties were overcome to a great extent and fairly trustworthy figures obtained.

The bending strength (or resistance to fracture by bending) was determined on test-pieces 150 mm. long, 20—30 mm. broad, and 10 mm. thick in the middle, in which a notch was cut on both sides previous to burning. One end of the test-piece was clamped fast up to the notch, and from the free end, at a measured distance from the notch, gradually increasing pressure was applied until the test-piece broke.

As the fired bodies were porous, it was exceedingly difficult to obtain homogeneity throughout the piece, and this was probably the chief cause in the lack of uniformity in the results. The resistance to fracture by bending was considerably greater than by tension, the average ratio of the values found being 2·84 : 1.

Various bodies were investigated to study the influence of plastic and lean clays, sand, felspar, and chalk on the properties of the fired body, the molecular compositions varying from 1·0 clay substance, 2·18 silica, 0·038 alumina, 0·349 fluxes, to 1·0 clay substance, 5·77 silica, 0·06 alumina, 0·217 fluxes.

Determinations of the bending and tensile strength were carried out on test-pieces burned at SK 01*a*, 4*a*, and 8—9 (1080°, 1160°, and 1250—1280°). The apparent porosity of the burnt pieces was also determined. The detailed results were given in a series of tables, and the authors summarised their conclusions as follows:—

1. Great divergences were met with in the strengths of different bodies, the variation being as great in some cases as 3:1.

2. The most important influence was the temperature of firing, the increase of strength of the body amounting to as much as 100 per cent. in the temperature range investigated (1080—1280°).

3. The increase of strength of the body through increased content of clay substance did not amount to more than 50 per cent. The influence of felspar on the strength became particularly apparent at about 1250°, and at this temperature an addition of 5 per cent. of felspar to the body increased the strength (cold) by 50 per cent.

4. At lower temperatures chalk had a slight beneficial influence on the strength of the body, but reduced it at higher temperatures. It did not decrease the porosity, as was the case with felspar.

5. No particular clay was indispensable in the production of stoneware bodies of high mechanical strength, but some required a much higher firing temperature than others to attain the desired result.

6. The bending strength of a good stoneware body should be at least 100 kg./cm. J. H. D.

214. The Nature and Resisting Properties of "Grog" Bricks in Tank Furnaces. J. Baldermann (*Sprechsaal*, 1919, **33**, 285).—Examination of such bricks and blocks with a lens showed that they contained particles of free quartz to a greater or less extent, and were porous owing to being of too coarse a texture.

In tank furnace practice the batch usually contained salt-cake, a portion of which floated undecomposed on the surface of the metal (as "glass gall") and penetrated into the pores of the blocks, causing increased attack and eventually partial disintegration. The particles of quartz dissolved in the fused salt-cake and gave rise to further cavities, and consequent increased attack, with the result that the blocks were badly corroded and particles became detached and appeared as stones in the glass.

The remedy was to make the flux-line blocks in tank furnaces of the same material as was used for making glasshouse pots, that is, of fine, close texture and as free as possible from quartz grains. Bottom blocks and bottom side blocks could be made of cheaper materials, since they had not to withstand the action of raw batch materials, particularly fused salt-cake.

In the author's experience, the extra cost of special flux-line blocks had been amply justified in the increased life of the furnace and the freedom of the glass from stones. J. H. D.

215. The Specific Heat and Heat Conductivity of Refractory Articles (*Sprechsaal*, 1919, **52**, 499).—The article summarised the contents of three published papers on the subject.

1. "Experiments on the Heat Conductivity of Refractory Building Materials."*

This paper dealt with methods of determining the heat conductivity of refractory blocks. The brick or block under test was built in with similar blocks above and below, and one face heated electrically by means of an iron plate, a temperature of 1550° being attained. Thermo-elements at the heated face and in borings in the block at fixed distances from the face allowed the temperature changes to be followed.

The heat conductivity (K) of the block was given from the equation $K = a^2cs$, where a^2 = the temperature gradient, c = the specific heat, and s = the specific volume of the block tested.

Some of the results obtained are given in the following table:—

Material.	Percentage composition.	Specific volume.	Specific heat at			Conductivity at		
			200°.	600°.	1200°.	200°.	600°.	1200°.
Grog brick.	About $40Al_2O_3$, $57SiO_2$.	1·88	0·225	0·272	0·305	0·0014	0·0022	0·0027
Grog brick.	$24{\cdot}34Al_2O_3$, $71{\cdot}05SiO_2$, $2{\cdot}46Fe_2O_3$.	1·77	0·217	0·263	0·304	0·0009	0·0012	—
Silica brick.	$96{\cdot}92SiO_2$, $1{\cdot}56Al_2O_3$, $0{\cdot}62Fe_2O_3$, $0{\cdot}97CaO$.	2·04	0·237	0·282	0·291	0·0013	0·0017	0·0021
Magnesite brick.	$88{\cdot}85MgO$, $9{\cdot}31Fe_2O_3$, $0{\cdot}35CaO$, $0{\cdot}17Al_2O_3$, $0{\cdot}2SiO_2$.	2·35	0·253	0·291	0·340	0·0011	0·0012	0·0014

The results showed that the variation in specific heat with the chemical composition of "grog" bricks was small, and the increase with rising temperature practically constant. The differences in the heat conductivity of the various types of bricks were fairly significant. In all cases the conductivity increased with rising temperature, although the temperatures of the experiments were below those at which the blocks had been burnt. After several heatings the "after-firing" effect appeared to approach an end. In the case of the silica brick, a sudden increase in the conductivity was observed above 1035°, possibly due to quartz inversion.

It was important that one should know the final values of the conductivity in the case of blocks for industrial purposes, and this should be ascertained from blocks which had been in actual industrial use over a considerable period.

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* E. Heyn, O. Bauer, and E. Wetzel: *Mitteilungen aus dem Kgl. Material-Prufungsamt.* Berlin-Lichterfelde. (33, 1914. Nos. 2 and 3.)

2. "The Mean Specific Heats of some Ceramic Bodies in Two Different Temperature Zones."*

This paper showed that the mean specific heats of grog, hard porcelain, and Marquardt's body were very similar, but that a pure magnesia body exhibited considerable variation.

3. "The Specific Heat of Refractory Products."†

In this paper the author gave the results of a number of determinations of the mean specific heat of twenty different refractory materials between 20° and 200°.

The results showed that for all materials composed chiefly of silica and alumina the mean specific heat may be taken as constant, with a constant increase with rising temperature. Between 20° and 200° the value was about 0·204, and between 20° and 400° 0·225. J. H. D.

216. The Geology of the Refractory Materials of the North of England. J. B. Atkinson and J. T. Stobbs (*Trans. Cer. Soc.*, 1918–19, xviii, 433).—The authors stated that nearly the whole of the refractory materials in the north of England were derived from the Carboniferous system, chiefly from the Coal Measures; to a less extent from the Millstone Grit and the Carboniferous Limestone series. In the Commondale district of the North Riding of Yorkshire some siliceous rock was obtained from the Estuarine series of the Lower Oolite. In Durham, the Permian formation furnished some dolomite. The Millstone Grit probably contained much valuable refractory material, but it had not been much explored.

Much valuable information was given, and the paper was illustrated with diagrams. C. M. M.

217. Ceramic Processes Associated with Colloid Phenomena. A. V. Bleininger (*J. Ind. Eng. Chem.*, 1920, **12**, 436).—In this paper the author presented some of the aspects of colloid chemistry which had a bearing upon the technology of clays.

Clays were mixtures of finely divided hydrated aluminium silicates with granular matter, such as quartz, felspar, mica, etc. The dispersed state of the aluminium silicates, chiefly $Al_2O_3,2SiO_2,2H_2O$—the clay substance—imparted the property of plasticity, the ability of the substance to be moulded when mixed with water, and to retain the shape imparted to it. Kaolinite, the pure type mineral, rarely occurred in clays, but had usually been reduced to particles of the magnitude of 5 μ or smaller admixed with colloidal material like ferric oxide and organic matter, and often stained by absorbed salts. In the natural state clays were not necessarily plastic. They might have been indurated by pressure or heat or other agency, so that they could not be made plastic without the aid of grinding. This was found to be the case with materials consisting of hydrated silicates other than $Al_2O_3,2SiO_2,2H_2O$, such as halloysite, pyrophylite, indianite, etc.

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* W. Steger (*Silikat Zeitschrift*, 1914, **2**, Part 3).

† W. Steger (*Silikat Zeitschrift*, 1914, **2**, Part 11).

A clay was said to be very plastic, fat, or sticky when the colloid matter was in excess; or sandy, weak, or non-plastic if the granular matter predominated. The colloidal characteristics were substantiated most effectively by ultramicroscopic examination. The author stated that recent work of Jerome Alexander had shown that Brownian movement was observed with practically every type of clay suspended in water. This movement varied from the rapid motion of the finer particles to the more sluggish motion of the larger particles or aggregates, or when hampered by the presence of electrolytes.

Clay suspensions were affected by various reagents, both electrolytes and non-electrolytes. The phenomenon of absorption was probably the most striking. An appreciable amount of the basic ion was absorbed, but practically none of the acid ion from solutions of salts like NH_4Cl, $BaCl_2$, $Al_2(SO_4)_3$, and $CuSO_4$. Deeply coloured solutions of metallic salts might thus be decolorised by passage through clay. This type of absorption followed the general exponential equation with fair agreement. As was common with all dispersed materials, salts as a class tended to coagulate clay, while bases deflocculate it. This type of reaction was of considerable technical importance. Thus NaOH, Na_2CO_3, or Na_2SiO_3 in increasing the dispersion of the clay particles produced a decided decrease in the viscosity of the system, and hence, according to Stokes's law, rendered possible a sharper and quicker separation of the granular matter of the clay substance proper, which fact had been made use of in the washing and purification of kaolins.

The so-called casting process illustrated another industrial application of the deflocculation of clays. In this case the constituents of the ceramic body were stirred with water containing about 0·3 per cent. of Na_2CO_3 and Na_2SiO_3 in terms of the dry weight of the clay materials to form a thick, but readily fluid, suspension. The addition of the alkaline reagents reduced the water content required to keep the mass in the liquid condition. In casting, the clay suspension was poured into a plaster mould which absorbed sufficient water to cause the mass to solidify. Coagulating agents, acids, and salts, however, were employed to increase the plasticity and strength of certain clays and to thicken suspensions of glazes and enamels.

The author stated that all the phenomena of deflocculation and coagulation occurred in stages. Thus when alkali was added to a clay suspension there was a decided viscosity minimum followed by alternating maxima and minima until the phases finally merged in a definite direction. Similar conditions prevailed also in a coagulation series, the phases being in reverse sequence. It had been found, also, that certain organic substances, like the tannins, reacted upon clay suspensions after the manner of alkalies, but the phases were less definite. They might also assume the function of a protective colloid in that they rendered the clay less sensitive to the action of electrolytes.

Viscosimeters had been used for estimating the deflocculating or coagulating effect of reagents, and such determinations of the viscosity or its reciprocal, the fluidity, of clay suspensions afforded a means of establishing the relative plasticity of different clays, inasmuch as equal concentrations would show fluidities inversely proportional to the general plastic nature of the materials.

An interesting phenomenon in connection with clay suspensions was the electrical deposition of the particles by a direct current upon the positive electrode against the flow of water away from it. The addition of small amounts of sodium hydroxide increased the charge of the clay particles and facilitated their deposition.

Plastic Clay.—Without doubt, the plasticity of clay was greatly affected by the presence of organic matter—humus, tannins, etc.—and it seemed to be a fact that acidity was conducive to the greatest development of this property. The ageing of clays improved their plastic working quality, and it was thought that this was partly due to the formation of organic acids, caused by bacterial action or chemical processes. It had been found that alkalies inhibited the plastic quality of clay to a very pronounced extent. Electrolytes increased or reduced the water required for the development of the plastic condition, and also the shrinkage upon drying.

Drying Shrinkage.—In this process the contraction in volume of the plastic clay was a typical property of colloid materials, and it might show a magnitude as much as the true volume of the clay itself. This shrinkage, therefore, was a criterion of the colloid nature of the clay, being the greater the more pronounced this development was. Electrolytes affected not only the magnitude of the contraction in drying, but the capillary flow of the water through the clay as well. The drying shrinkage was the greater the more slowly evaporation of the water was allowed to take place, and *vice versâ*.

Firing of Clay.—The dehydration was endothermic and was associated with a marked increase in molecular volume. At about 900° an exothermic reaction occurred which might be associated with an irreversible change of a colloidal nature or the dissociation of the aluminium silicate, perhaps into Al_2O_3,SiO_2 and silica.

The external clay volume contracted as the firing temperature was raised, especially if fluxes were present, due to the effect of surface tension, until the heat intensity was sufficient to bring about practically complete closing of the pore space. The clay was then said to be vitrified.

Wherever the chemical composition and the heat treatment permitted it, the end result was the partial elimination of the colloid phases and their replacement by crystalline identities. Thus the clay substance decomposed into *sillimanite* and silica.

C. M. M.

218. A Possible Explanation of Failure under Load at High Temperatures as Displayed by Fireclay Refractories.

A. S. Watts (*J. Amer. Cer. Soc.*, 1920, **3**, 448).—It was generally regarded as a fact that all clay refractories failed under load when a temperature of 1300° was reached. Bleininger and Brown suggested that high flux content rather than high silica content was a cause of inferiority and the development of easily fusible silicates at low temperatures, and the progressive solution of additional silica and alumina with increased temperature or with a prolonged exposure to the same temperature was sufficient cause for the failure of the refractory under load. But many bricks showed weakness under load at temperatures below 1300°, despite low alkali content and the near approximation to *kaolinite* of the Al_2O_3–SiO_2 ratio. Bleininger and Brown's results showed that a brick with high silica content and low alumina content stood the load test, whereas three bricks with alumina and silica contents approaching the *kaolinite* formula failed. Flux contents were very similar, and the present author considered that the difference in behaviour of the high silica brick was due either to high silica or low alumina. Bleininger and Brown further admitted the advantage of reducing the flux content by the addition of pure silica in the form of clean sandstone, but did not note the effect of reduction of the alumina content. They also suggested that hard burned bricks were superior to soft burned bricks, justifying that by the fact that the more fusible bond clays absorbed some refractory flint clay, and were thus improved as regarded resistance to load.

The author was therefore led to inquire whether the weakness of the high alumina clay refractories was really due to such chemical solution at higher temperatures or could be more correctly attributed to a period of physical weakness produced in the mass by the decomposition of the kaolin and the recombination of the alumina and silica as *sillimanite*.

The author had proved that *sillimanite* could be formed at 1170°. Vitrification was not necessary for the formation of *sillimanite*, and Glasenapp had shown that the development of *sillimanite* was not a case of crystallisation out of solution, but one of molecular rearrangement by which all clays became crystalline at high temperatures coincident with the decomposition of the clay substance. Thus the mechanical failure of the mass would begin as soon as the temperature was sufficiently high for the molecular rearrangement to take place. Zoellner showed that three kaolins fired at cone 15 yielded from 20 to 23 per cent. of *sillimanite*, but two ball clays, with almost the same alumina content as the kaolins and vitrifying at cone 15, yielded less than 6 per cent. of *sillimanite*.

In accordance with Zoellner's results, the author mentioned that saggars made from ball clays and highly siliceous clay, such as a wad clay, were far superior to any produced from the best flint and plastic fireclays, and whereas a high *sillimanite* development was found in fireclay saggars, it was absent from saggars made from ball and wad clays. Further investigation was, however, necessary before a positive statement could be made on this particular failure question.

An interesting discussion followed the paper. F. W. H.

219. Note on the Load Behaviour of Aluminous Refractories. A. V. Bleininger (*J. Amer. Cer. Soc.*, 1920, **3**, 155).—The results obtained were as follows:—

	Composition.							
No.	Calcined flint clay, per cent.	Artificial *sillimanite*, per cent.	Plastic fire clay, per cent.	Kaolin, per cent.	Temp. of firing. Cone.	Firing shrinkage, per cent.	Contraction in load test, per cent.	Softening point, Cone.
1.	75	—	12·5	12·5	14	1·06	2·40	33
2*a*.	80	—	10·0	10·0	14	0·47	2·80	33
2*b*.	80	—	10·0	10·0	16	0·35	0·84	33
3.	80	—	—	20·0	16	0·83	0·88	35
4.	—	80	10·0	10·0	16	—	0·61	above 35
5.	—	80	—	20·0	16	—	0·48	above 35

The artificially prepared *sillimanite* consisted of 71·6 per cent. kaolin and 28·4 per cent. anhydrous alumina. The mixture No. 1 was moulded into standard sized bricks by the soft mud process and the others by dry pressing under a pressure of 5000 pounds per square inch. In the case of No. 1, the load test, pressure being maintained at 50 pounds per square inch, was carried out at 1350° and, for the others, at 1400°. The contraction was expressed in percentage of the original length of the brick. The fusion test was carried out in a pot furnace using natural gas with air at a pressure of 40 pounds per square inch, the maximum temperature obtained being at cone 35.

Providing the burning temperature was sufficiently high, refractories high in alumina could be made which resisted load conditions and were practically constant in volume. The use of synthetic *sillimanite* necessitated a calcination temperature sufficiently high for the ready transformation of the mixture into the compound desired, and intimate mixing of the kaolin and alumina before calcination. F. W. H.

220. Refractory Properties of Aluminous Products. H. Le Chatelier and B. Bogitch (*Compt. rend.*, 1919, **169**, 495).—In spite of the highly refractory nature of bauxite, this material has not been a success when used in the construction of steel furnaces, on account of its great porosity and considerable shrinkage. The low expansion of alumina renders it useful in increasing the resistance to sudden change of temperature, and for this reason bauxite is often mixed with a small quantity of clay. Too great porosity and shrinkage are eliminated by fusing the bauxite, either in the electric furnace, when the product, known as alundum, loses its iron oxide and silica, as silicate of iron, or in the cupola, by Lecesne's process, when the less expensive, but less pure, corindite is produced, retaining the iron oxide and the silica. This material softens at a temperature of about 1800°, but, when mixed with 10 per cent. of kaolin, or of syrupy sodium silicate mixed with its own volume of water, it shows no shrinkage up to a temperature of 1600°, and can be heated rapidly without any sign of cracking.

Experiments were made by the authors to test the resistance to heat of certain bricks, carborundum being used for comparison, with pure bauxite and corindite. The chemical compositions of the products used were determined, and the coarsely ground corindite and carborundum were graded.

The following specimens were studied, pure water being used to produce plastic pastes, which were moulded by hand, and heated for three hours at a temperature of 1200° for corindite and 1400° for carborundum:—

1. Brick of pure bauxite, moulded by pressure, and dried at 1300° in a large furnace.
2. Corindite with 10 per cent. of bauxite.
3. Corindite with 10 per cent. of kaolin.
4. Corindite with 2 per cent. of solution of syrupy sodium silicate.
5. Corindite with 6·5 per cent. of solution of syrupy silicate.
6. Carborundum with 10 per cent. of kaolin.

The resistance to crushing, on heating, was investigated, the pressure at which the height of the specimen test-piece was reduced by one-third being measured. All these specimens became plastic at temperatures between 1200° and 1500°. Although alumina and carborundum are infusible at these temperatures, the particles move freely, without any cohesion, in a melted mass, whereas silica, although more fusible, forms a continuous network, due to the crystallisation of tridymite. Alumina, then, like magnesia, although highly refractory, yields bricks which cannot resist heat and pressure.

The results of the experiments show that the mixtures with silicate of sodium are less resistant than those containing kaolin, but for the construction of small laboratory furnaces, where there is no great weight to support, they are very useful, as, on drying in the cold, they become hard enough to manipulate with safety up to a temperature of 1400°.

Mixtures containing 95 per cent. of alumina, and consisting of (*a*) calcined alumina 80, white bauxite 20, and (*b*) alumina 90, kaolin 10, were found to break in all directions and contract enormously on first heating, but if they were then crushed, mixed with one-quarter the weight of the same raw mixture, moulded under pressure, and again heated to 1700°, they did not soften up to a temperature of 1600°. At this temperature, their resistance to fracture was 20—40 kilos. per sq. cm., and these products could be heated up to a temperature of 1600° very rapidly, whereas silica bricks would need careful heating. V. D.

221. Comparative Tests of Machine-made and Hand-made Silica Bricks. W. Emery and L. Bradshaw (*Gas Journal*, 1920, **150**, 577).—The bricks were prepared from Dinas silica rock, using lime as binding agent. Part of the material was moulded into bricks by hand and a second portion by power press, those made by machine being more accurately shaped than those made by hand.

The results showed that machine-made silica bricks were in no way inferior to the hand-made variety, but, on the contrary, in certain ways they were superior. Similar results were obtained for both types of bricks in tests on porosity, refractoriness with and without load, reversible expansion at 1200°, and, after-expansion on heating to 1350°. The apparent specific gravity of the machine-made bricks was 1·85 and that of the hand-made bricks was 1·8, and the resistance to crushing of the latter type was 28 per cent. less than that of the former type. When subjected to the action of a sand blast the machine-made bricks gave the greater resistance towards abrasion.

Spalling was tested, first, by determining the loss in weight after heating and quenching alternately, and, secondly, by determining the reduction in strength after heating to 600° and then allowing to cool. The best results in both tests were given by the machine-made bricks.

F. W. H.

222. The Effect of the Method of Preparation on the Viscosity of a Casting Slip. V. S. Schory (*J. Amer. Cer. Soc.*, 1920, **3**, 286).—Experiments were made during which it was attempted to keep all possibly variable factors constant and determine the effect on the slip of different methods of preparation. The body was prepared by blunging, screening, and filter-pressing, and in every case the same proportions of body, water, sodium carbonate, and sodium silicate were used. Using a viscosimeter of the Bureau of Standards type, the relative time of flow of the casting slips was compared with that of water at 15°. The instrument delivered 200 c.c. of water in 14·8 seconds, and the time of flow of each slip was divided by 14·8 to obtain a figure which was termed the viscosity of the slip.

In the first six cases the slip was prepared by blunging in the ordinary double blunger, and in a further six cases by grinding in a pebble mill. The sodium carbonate and sodium silicate were added in the form of 8 per cent. solutions, and the amounts of anhydrous reagents added were sodium carbonate 0·027 per cent. and sodium silicate 0·036 per cent. of the dry weight of the body. The specific gravity of the slips was 1·75, corresponding to a water content of approximately 30·5 per cent.

The results obtained were as follows:—

Method of preparation.	Viscosity.	Method of preparation.	Viscosity
1	5·21	7	4·68
2	2·72	8	3·64
3	4·77	9	5·09
4	3·07	10	10·3
5	4·60	11	4·18
6	3·78	12	8·3

In Nos. 1 and 3 both alkaline reagents were added at the same time; in Nos. 5 and 6 the sodium silicate was added early in the operation, and sodium carbonate last of all; in Nos. 2 and 4 the sodium carbonate was added early and the sodium silicate last. Of Nos. 7 to 12, three of the slips were made from filter-press cake containing 21 per cent. of water, and three from crushed, dried cake. The slips made from the wet cake were all of a lower viscosity than those made from dry cake by corresponding processes. Similar tests made on another body confirmed the results previously obtained.

Further tests were carried out on slips made by the foregoing methods from the second body, these slips containing such proportions of the alkaline reagents as to give slips with approximately the same viscosity. The viscosities of the slips were between 3·35 and 3·65. The percentages of reagents used were:—

Method of preparation.	Sodium carbonate, per cent.	Sodium silicate, per cent.	Method of preparation.	Sodium carbonate, per cent.	Sodium silicate, per cent.
1	0·0745	0·099	7..............	0·0585	0·078
2	0·0545	0·0725	8..............	0·0465	0·062
3	0·0645	0·086	9..............	0·0595	0·079
4	0·0570	0·076	10..............	0·0855	0·114
5	0·0645	0·086	11..............	0·057	0·076
6	0·0620	0·083	12..............	0·0805	0·1075

The slips were cast in plaster moulds. Of the slips prepared by blunging (Nos. 1 to 6), those with the lowest alkaline reagent content gave the firmest casts; the methods of preparation requiring the greater amounts of sodium salts to bring the slips to their best casting condition gave the softer casts. No. 10, prepared by grinding with the largest percentage of salts, gave the softest cast. Apart from the fact that blunged slips with the lowest content of alkaline reagents gave the firmest casts, high alkaline content tended to cause a frost-like growth on the moulds, which after a time became a comparatively impervious film and hindered drying. The salts also separated out on the ware when removed from the mould, and consequently the surface layers were rendered more fusible. F. W. H.

223. Elutriation Tests on American Kaolins. H. G. Schurecht (*J. Amer. Cer. Soc.*, 1920, **3**, 355).—A description was given of the elutriation of clays, using the Schulze elutriator, and the precautions necessary for obtaining accurate results were indicated. The apparatus was described in detail, and also the method of standardisation. The velocities of flow for the elutriation cans were respectively 0·347, 0·180, 0·059, and 0·0197 millimetre per second.

The material passing through a 200-mesh sieve was used, and deflocculated by sodium hydroxide. Distilled water was better than tap-water, since the soluble salts in tap-water caused coagulation of the clay particles, and consequent settling as larger grains.

Elutriation Tests on English Clays using Distilled Water.

Sample.	20 mesh.	20 to 65 mesh.	65 to 100 mesh.	100 to 200 mesh.	Can 1. Velocity 0·347 mm.	Can 2. Velocity 0·180 mm.	Can 3. Velocity 0·059 mm.	Can 4. Velocity 0·0197 mm.	Overflow.	Can 3 + Can 4 + Overflow.	Total surface factor.
English China Clay.											
Percentage	0	0	0	0	5·93	2·70	18·08	32·40	40·75	91·23	—
Diameter in millimetre	—	—	—	—	0·0230	0·0192	0·0125	0·0076	0·0048	0·0079	—
Surface factor	—	—	—	—	257·80	140·60	1446·00	4263·0	8296·0	14005·0	14463·4
English Ball Clay.											
Percentage	0	0·095	0·030	0·065	0·150	0·200	0·300	0·550	98·55	99·40	—
Diameter in millimetre	—	0·566	0·178	0·1144	0·0231	0·0122	0·0096	0·0066	0·0042	—	—
Surface factor	—	—	—	—	—	—	—	—	—	—	—

The deflocculated clay was fed into the elutriator drop by drop, and during this operation the velocity of flow was reduced by one-third. Results were more trustworthy when the residues were stirred at intervals.

The grain size of each residue was measured under the microscope by taking the average of at least sixty grains. For calculating the average size of grain, the following formula, where d_1 represents the maximum diameter and d_2 the minimum diameter, was used:—

$$D = \sqrt[3]{\frac{(d_1+d_2)\,(d_1^2+d_2^2)}{4}}.$$

To express the fineness of grain, which was inversely proportional to the diameter of the particles, the Jackson-Purdy surface factor was used.

The results tabulated were extensive, and comprised English and American clays, comparing observed with calculated values, and the values obtained using distilled water with those obtained using tap-water. Using distilled water, the observed diameters closely agreed with the calculated values obtained by using Schöne's empirical formula. The English ball clay examined contained 98·55 per cent. of fine material carried away by a flow of 0·0197 millimetre per second, whilst only 40·75 per cent. of English kaolin was carried off at that velocity. The greater plasticity and bonding strength of the ball clays were, in the author's opinion, due largely to their finer grains. The results on p. 157 were tabulated for the English clays. F. W. H.

224. The Classification of Clays on a Ceramic Basis. A. S. Watts (*J. Amer. Cer. Soc.*, 1920, **3**, 247).—The author discussed the confusion arising from the lack of definiteness in classifying clays. He suggested a classification based on five properties, namely, colour, shrinkage, bonding strength, vitrification, and fusion, the last two properties being possibly combined under the term "refractoriness."

As regards colour, the terms white, cream, buff, and tan might be used for the shades closely related to white, and then distinct colours. Shrinkage should be divided into two sections, drying and total shrinkage, both expressed as percentages of the original wet dimensions. The drying shrinkage might be separated into five divisions, as, for example, less than 3 per cent., 3 to 6 per cent., 6 to 9 per cent., 9 to 12 per cent., and more than 12 per cent. Similarly, total shrinkage at some definite temperature might be subdivided into those less than 4 per cent., 4 to 8 per cent., 8 to 12 per cent., 12 to 16 per cent., and more than 16 per cent. Bonding strength should be determined on a mixture of equal parts by weight of the clay and a standard sand by the effect on shrinkage, or, better, by determining the modulus of rupture on a mixture of 50 per cent. by weight of clay and 50 per cent. by weight of potters' flint (Report of the Committee on Standards, 1919, pp. 40—43). The clays could then be classified as having a modulus of 800 lb. per square inch or more, 400 to 800 lb. per square inch, 200 to 400 lb. per square inch, 100 to 200 lb. per square inch, or less than 100 lb. per square inch.

Vitrification should be taken as referring to the stage of firing at which the clay showed no absorption. The vitrification and fusion, or "softening-point," data should be expressed in terms of cones and divided into five sections, namely, below cone 5, between cones 5 and 15, 15 and 25, 25 and 30, and above cone 30.

F. W. H.

225. Investigations on Zirconium. J. W. Marden and M. N. Rich (*J. Ind. Eng. Chem.*, 1920, **12**, 651).—The authors stated that the following was an abstract of a report to be published by the U.S. Bureau of Mines in the near future.

I. Preparation of Zirconium Oxide.

Most of the experimental work was done on the Brazilian ore *zirkite*, which consisted of a mixture of *zircon* ($ZrSiO_4$) and *baddeleyite* (ZrO_2) containing about 73—75 per cent. of ZrO_2.

In decomposing the zirconium ores the following methods were employed:—

(*a*) Fusion with $NaHSO_4$, commercial nitre cake, etc.

(*b*) Fusion with caustic soda or soda ash, together with sodium peroxide.

(*c*) Fusion with $NaHF_2$ or treatment with hydrofluoric acid.

(*d*) Ignition with charcoal and subsequent chloridising.

(*e*) Electric arc fusions of zircon, CaO and carbon, leaching with water, and chloridising the residue.

After decomposition of the ore, the zirconium was brought into solution, and the hydroxide precipitated and converted to the oxide by ignition. It might further be purified by dissolving in acids and reprecipitating, or by recrystallisation as the oxychloride. The authors made many trials of the above methods on quantities of the ore varying from 1 gram to 10 lb. On a commercial scale the use of fluorides and saltpetre was found to be expensive. The most efficient and successful methods proved to be the phosphate method and the basic sulphate.

II. Preparation of Pure Potassium Fluorzirconate and the Crystalline Zirconium Aluminium Alloys.

The quickest and most satisfactory method was to dissolve ZrO_2 in hydrofluoric acid and purify the product by successive crystallisation. The potassium salt was formed by adding potassium carbonate solution to a solution of K_2ZrF_6, obtained as above.

Aluminide (Zr_3Al_4), the so-called "crystalline zirconium," could be prepared by fusing K_2ZrF_6 in a graphite dish and adding to the fusion one and a-half times its weight of aluminium.

A crystalline silver zirconium alloy might also be prepared by the alumino-thermic reduction.

III. Preparation of Zirconium Metal.

Four varieties were referred to: amorphous, crystalline, graphitoidal, and sintered.

The following methods had been employed:—

Amorphous.—(1) Reduction of K_2ZrF_6 with a small excess of sodium in an iron tube. (2) Passing $ZrCl_4$ over heated sodium. (3) Reduction of ZrO_2 with calcium.

Crystalline.—This had proved to be an alloy of zirconium and aluminium.

Graphitoidal.—After repeated failures to prepare this form, the authors held that there was no such variety.

Sintered or "Coherent."—(1) Alumino-thermic reductions. (2) Reduction of ZrO_2 with carbon.

The authors appended a list of both physical and chemical properties of the amorphous and coherent forms of zirconium.

C. M. M.

226. Improved Glass Tank Furnace. Harry E. De Vaughn and Walter A. Jones (U.S.A. Pat., November 25th, 1919, No. **1322767**. Filed October 6th, 1916, No. 124090).—The tank to which the improvement is applied is used for drawing sheet glass, and is of the type in which the crown and the topstone of the drawing end are supported on piers built up from the bottom of the tank. The destruction of these piers entails loss of production while repairs are undertaken, and adversely affects the quality of the glass through the solution of the refractory material. In order to avoid these disadvantages, the inventor, instead of using piers, suspends the skew blocks, 28, that support the crown and the topstone, from girders above the tank. The suspending rods, 24, are screwed into members, 26, on the underside of the

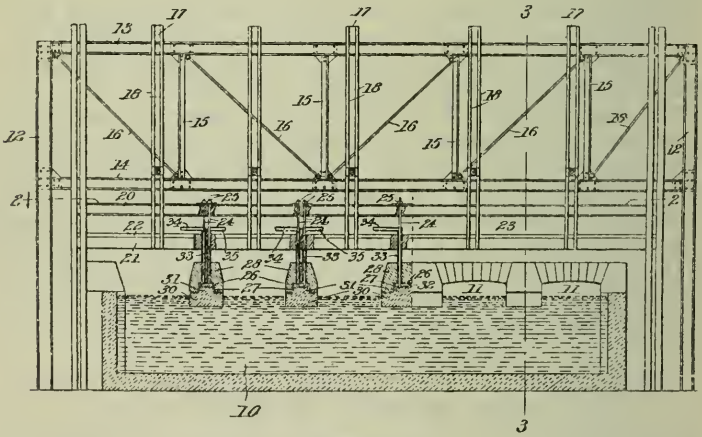

Fig. 122.

skew blocks, and the rods may be water-cooled. The members, 26, are also protected by blocks, 30, floating on the metal in the tank.

G. D.

227. The Working of "Siphon" Tanks. H. KNOBLAUCH (*Sprechsaal*, 1919 **52**, 311).—In the author's opinion, for ordinary tank-furnace practice to be efficient, a free glass surface of about 40 sq. metres was necessary, as if less than this either the temperature ruling in the furnace would be too low to ensure proper founding conditions or the glass at the working holes would be too hot and too fluid for working. Small tanks were only suitable for intermittent working, that is, alternate melting and working out. Small tanks could be used successfully for continuous working if arranged as "siphon tanks." Siphon tanks were similar in general construction to ordinary tanks, with the particular feature that "siphons" or bent, curved fireclay pipes were introduced into the molten glass. The lower ends of these pipes dipped below the surface of the glass to any desired depth, so that the fluid glass was forced upwards into the "siphon." The upper, exposed end of the "siphon" constituted the working hole.

One distinct advantage of the siphon tank was that since the glass was drawn from a deeper level in the tank than was the case in ordinary tank practice—using rings or boats—it was more homogeneous and thoroughly melted. In the opinion of the author, under customary tank-working conditions, the glass was frequently worked from too shallow a layer, and so was gathered too soon after being melted and without having time to become properly homogeneous, while a large quantity of well melted and thoroughly homogeneous glass remained in the tank stagnant.

The author described a tank suitable for siphon work, of which the principal features were as follows:—

A rectangular tank with glass surface 10 m. × 1 m. and depth of glass 1 m.

Nine siphons (and working holes) along one side and six along the other, the three vacant spaces being utilised as filling-on holes to allow of the batch being spread out as evenly as possible.

The furnace was heated by gas, four burners being placed in each of the ends of the furnace, and the direction of the flames reversed periodically. Gas and air entered in parallel currents, a small mixing chamber being built at the front of the burner. The mixing of gas and air occurred slowly, so that a long flame resulted.

The gas- and air-reversing valves were operated by mechanism from the floor of the glass-house, gas and air being reversed simultaneously. The construction was such that the gas and air regenerator chambers could be exchanged at will to ensure equable heating in the furnace. The supply of gas to each regenerator could be regulated by an adjustment in the valve cover.*

The regenerators were placed at each side under the furnace, and directly beneath the burners and between these and the regenerators were chambers to retain batch dust, etc., from the furnace. The author claimed that in such a furnace about 11½ tons of well-melted, homogeneous glass could be withdrawn in 24 hours, the fuel consumption being from 7½ to 8 tons of coal, with an approximate calorific value of 6500 cals.

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* For detailed description, see *Stahl u. Eisen*, 1912, No. 38.

The construction of the furnace was illustrated by several diagrams. J. H. D.

228. The Durability of the Burners in Glass-melting Furnaces. H. Knoblauch (*Sprechsaal*, 1919, **52**, 407).—Abnormal working of a furnace always led to a reduction in its working life, even when constructed of the best materials, but frequently the cause of the shortened life of a furnace was due to the poor quality of the refractory materials and the inefficient method of working. Irregularity in reversing was a frequent source of failure of the burners, particularly in the case of regenerative gas-fired pot furnaces. The life of the burners was influenced by their construction and the correct regulation of the flame in the furnace. The best melting conditions were attained when a slight positive pressure was maintained in the furnace, as evidenced by the tendency of the flame to flicker outwards through any casual cracks and the lack of any tendency for air to be drawn into the furnace from outside. The amount of flame generated should be as small as possible consistent with the attainment of the requisite temperature. Gas and air should be burnt in the furnace and the chimney draught reduced until only just sufficient to carry away the burnt gases. If the temperature required was not reached, more gas and more air should be sent into the furnace and the chimney draught correspondingly increased until the required temperature was attained. If the chimney draught was too great the flames were drawn into the burners, causing more rapid corrosion and also leading to fuel wastage.

The author described the failure of burners of faulty construction and under faulty working conditions. The type of furnace referred to was the gas-fired pot furnace, either of the "Bütten" type or with slotted burners. Two burners were built in the sole of the furnace, the flame forming an arc between them, and each burner serving in turn as the exit flue for the gases.

The "Bütten" type—with open burners in which gas and air mix below the furnace floor-level—had not proved very satisfactory, since combustion took place in the burner itself and not entirely in the furnace. This led to excessive temperature in the burner and consequent rapid burning away, particularly in the lower part of the burner. The burners should not be significantly narrower at the top than at the bottom, since this increased the tendency of the burners to burn hollow.

Better results were obtained with slotted burners, that is, burners in which gas and air were conducted independently through parallel slits into the furnace, where they mixed and burned.

Here very little combustion occurred inside the burner, which consequently had a longer working life. The gas and air mixed rather slowly, so that this type of burner was unsuitable for very small furnaces, since there was the danger that the gases were incompletely burnt by the time they reached the exits. Shortening the dividing walls between the slits helped to prevent this, since not only did it give the flame a rather longer travel, but it also tended to mix the air and gas rather more rapidly.

Slotted burners were usually corroded or melted away from the top downwards. When this occurred with open burners it was a certain indication that the draught had been too great, and that flame as well as burnt gases had been drawn into the burner.

The author described a furnace with burners of the open type in which the burner was divided into two parts by a fireclay partition; that is, it was a compromise between an open and a slotted burner. To ensure the equal distribution of gas and air into each section of the burner, corresponding division walls were erected in the regenerators, so that each half of the burner was connected with a separate half of the regenerator, and since the gases passing through separate halves of the regenerators could be controlled by dampers, it was possible to regulate the flame distribution in the furnace as desired. This was of considerable value, especially in the case of getting heat to the corner pots.

The various points raised were well illustrated by sketches.

J. H. D.

229. Annealing Apparatus. E. L. Zihlmann (U.S.A. Pat., February 26th, 1918, No. **1257441**. Filed July 9th, 1917, No. 179497).—The invention consists of a hot stove in which blown ware is placed after being knocked off from the iron until a certain number of pieces have been made, the whole being then taken-in to the lehr. It is explained that the device is designed to overcome the shortage of boys for taking-in.

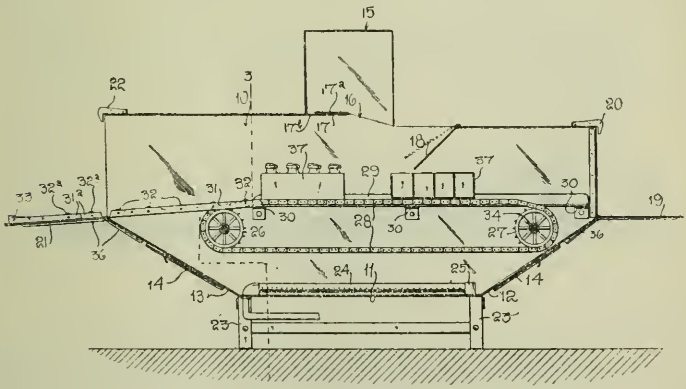


Fig. 123.

The device, shown in sectional elevation in Fig. 123, consists of a sheet-iron casing, 10, about 60 inches long by 18 inches wide and 20 inches high, heated by gas burners, 24, and having in its top a hood, 15, covering an aperture, 16, through which the ware is inserted. The ware is placed in compartmented pans, 37, which are supported on an endless chain conveyor, 28, that can be moved by hand when a pan is filled. Doors, 19, 21, are fitted to the ends of the casing, and when it is desired to remove a pan full of ware, the door, 21, is lowered, and the filled pan rolls out on rollers, 32^a. The pan is now carried to the lehr, emptied, and returned to the casing through the door, 19. G. D.

230. Muffle Lehr. H. M. Thompson (U.S.A. Pat., February 19th, 1918, No. **1257150**. Filed October 1st, 1917, No. 194132).—Relates to a muffle lehr designed to prevent the leakage of gas between the combustion chamber and the muffle or annealing chamber, and thus avoid discoloration of the ware. The lehr, shown in sectional elevation in Fig. 124, consists of side walls and an arched crown, 6, as usual, but below the crown is a flat roof formed of tiles, 12, supported on the flanges of inverted **T**-girders, 10, that are suspended by rods, 11, from outside beams, 10. The tiles thus form the floor of the combustion chamber, 7, which it separates from the annealing chamber, 4, containing an endless band, 5, the ware on the band being annealed by heat conducted through the tiles. Division walls, 9, having openings or ports, 7^e, staggered in respect to one another, break up the combustion chamber, 7, into smaller chambers, forming a tortuous passage, through which the gas must pass to reach the flue, 8. When natural gas, oil, or clean producer gas is used as fuel, it is admitted

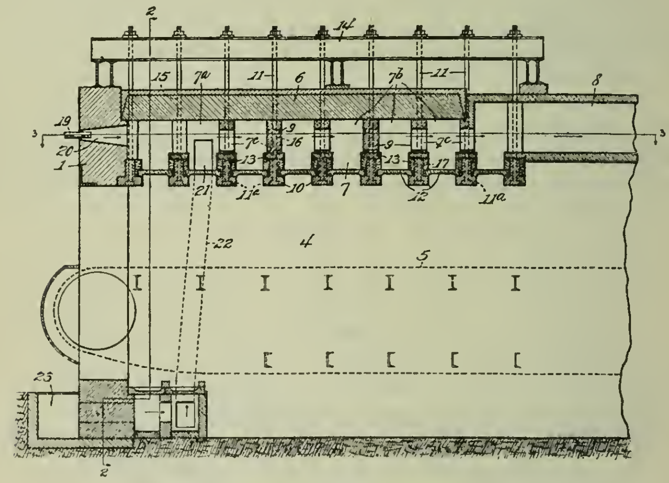


Fig. 124.

through openings, 20, in the front wall of the chamber, 7. Coal may be burned in a grate, 23, communicating with the chamber, 7, by flues, 22, in the side walls of the lehr. G. D.

231. On the New Method of Setting Regenerator Chambers. G. Suchy (*Sprechsaal*, 1919, **29**, 247).—The author continued a discussion on the subject of regenerator chambers in which the chequer work was built up on a series of carriages which could be withdrawn and replaced at will. The idea was not new, but had never met with general acceptance.

In the usual type of furnace—if the dampers were closed during filling-on and correctly regulated during founding, so as to avoid excessive draught—batch dust would not be drawn into the regenerators, and their subsequent stopping up or collapse would be hindered to such an extent that re-setting should not be necessary for one to one and a-half years. After this period the regenerators should be re-set entirely.

In a tank furnace conditions were different. Batch was filled on at hourly intervals and dampers were rarely altered, so that much more batch dust was drawn into the regenerators. The "new" system might be of advantage under these conditions, but as the chambers would have to be re-set along their length the process would be very disagreeable.

Glass from the siege could be prevented from leaking into the regenerators to a great extent by paying particular attention to the covering of the chambers. As the furnace grew older, however, cracks developed, and some glass frequently found a way into the chambers. To avoid this as far as possible, the following procedure was recommended. Before the first pot setting rake over the siege a dry mixture of two-thirds quartz sand and one-third plastic clay to fill up all cracks. At each subsequent pot setting fill up all cracks or channels with the same mixture made into a slip with water, and then cover with a liberal coating of sand. In this way the siege remained intact, and glass could not leak through.

Soft glasses, such as the more fusible lime–soda glasses, could usually be made in furnaces depending chiefly on top heating, but for harder glasses, such as Bohemian crystal, bottom heat was essential. This could be attained by correct furnace practice. For instance, in the improved Siebert furnace, where the regenerators were close under the furnace, so soon as the second filling-on had melted down, the dampers should be lowered. The heat was driven upwards from regenerators and under-furnace, and the flames became clearer, and a steady, successful found resulted.

Overflowing from the glass pocket into the chambers could be prevented by closing the pocket with a fireclay stopper luted lightly with fireclay. When the glass pocket became too full, the fluid glass forced out the stopper and flowed into a special pit, thus obviating the arduous work of drawing the glass from the pocket.

The author agreed that elliptical regenerator blocks were preferable to the ordinary form, but from experience preferred blocks $32 \times 10 \times 10$ cm., on the ground that they distributed the heat more uniformly throughout the chambers. J. H. D.

232. On the New Method of Setting Regenerator Chambers. J. Baldermann (*Sprechsaal*, 1919, **52**, 363).—The author maintained that the system of setting regenerator chambers by means of movable carriages had proved efficient in practice. For each chamber three carriages were necessary, and all four chambers could be re-set in two to three hours, whereas in the case of badly fused chambers it took from forty-eight to sixty hours to put these into good order by the older method.

With regard to other points raised in the discussion, the siege of the furnace could be maintained in much better condition by the use of grog than by using the sand–clay mixture recommended by Suchy, since well-burned grog was not so readily attacked by the overflowing glass as were sand and clay, and consequently remained permanent, whereas sand and clay were dissolved by the glass, leaving exposed cracks and channels in the siege. Further, the pots did not bind so firmly to the siege when set on coarse grog as when sand is used. In a furnace with top-flame heating it was quite possible to melt a glass containing 30 parts of soda to 100 parts of sand, or even somewhat harder. The harder the glass the cheaper it was and the better the colour.

The author pointed out that if the dampers were closed during filling-on the result would be that the flame would be driven out through the filling-on holes. He approved the idea of the automatic emptying of the glass pocket, but it remained to be seen whether this would work out well in practice. J. H. D.

VIII.—Chemical Analysis.

233. Methods for the Determination of Zirconium. J. W. Marden and M. N. Rich (*J. Ind. Eng. Chem.*, 1920, **12**, 651.)

The following methods were tested, and a table given as to their relative merits:—

1. Phosphate precipitation. Hillebrand, *U.S. Geol. Survey*, Bull. **73** (1900); Lundell and Knowles, *J. Amer. Chem. Soc.*, 1919, **41**, 1801; Nicolardot and Reglade, *Compt. rend.*, 1919, **168**, 348.

2. Thiosulphate or SO_2 precipitation. Baskerville, *J. Amer. Chem. Soc.*, 1894, **16**, 475; Ferguson, *Eng. Min. J.*, 1918, **106**, 356, 793.

3. Iodate separation. Davis, *Amer. Chem. J.*, 1889, **11**, 25.

4. Peroxide separation. Bailey, *J. Chem. Soc.*, 1886, **149**, 481; Walker, *J. Amer. Chem. Soc.*, 1898, **20**, 513.

5. Phenylhydrazine precipitation. Allen, *J. Amer. Chem. Soc.*, 1903, **25**, 421.

6. Cupferron precipitation. Ferrari, *Atti ist. Venata Scienze Lettere ed arti*, 1914, **73**, 445; Brown, *J. Amer. Chem. Soc.*, 1917, **39**, 2358.

7. Fluoride separation. Headden, *Proc. Colo. Sci. Soc.*, 1917, **11**, 185.

The authors recommended the following method of analysis:—

Preparation of Sample.—Thorough grinding of the sample was important.

Method of Solution and Separation of Silica.—Alloys were treated with aqua regia and evaporated nearly to dryness to separate the silica, which was filtered, washed and ignited, and then determined by the usual method of volatilisation with HF and H_2SO_4. After the silica had been removed, the filtrate, containing 5 per cent. of H_2SO_4, was made up to a known volume, and suitable aliquot parts of this solution were taken for the determination of zirconium. In no case should more than 0·1 gram of ZrO_2 be taken.

In the case of an ore, 1 gram of the substance was fused in a nickel crucible with four parts of NaOH and one part of Na_2O_2. The fused mass was extracted with water and acidified with sulphuric acid. Silica was then separated as above.

Analysis of Solution containing Fe, Al, Cr, Ni, Mo, W, Ni, Co, Zr, Ti, *and* P.—An aliquot portion of this filtrate was heated to about 90° and ammonia added until a slight permanent precipitate was formed. Dilute HCl (1 : 1) was added from a burette until the solution was just clear again, and then five more drops of HCl were added. Three c.c. of an aqueous solution of phenylhydrazine were added, the solution was stirred vigorously, and filtered immediately. The precipitate was washed with hot water and ignited in a platinum crucible. This separated practically all the iron from the zirconium, titanium, and aluminium. To separate further the zirconium and titanium from aluminium the following method was employed. The residue was fused in the platinum crucible with 5—10 grams of Na_2CO_3 and 1 gram of KNO_3. Disintegration with hot water, filtering, and washing followed. The residue now contained zirconium and titanium free from interfering substances (Al, etc.), except perhaps traces of iron. The sodium, zirconate, and titanate were ignited in a platinum crucible, the residue fused with bisulphate, and the zirconium estimated by any of the abovementioned methods.

If zirconium alone be desired, the following method might be employed. A known volume of the filtrate from the silica, together with 2 c.c. of H_2O_2, was heated nearly to boiling, and a slight excess of disodium phosphate solution added. A white or greenish-white, flocculent, gelatinous precipitate was formed. It was allowed to stand for at least two hours and then filtered, washing with hot dilute sulphuric acid. It was then ignited in a platinum crucible, and finally the blast applied to remove carbonaceous matter. This ignition was one of the most difficult steps of the whole procedure. The weight of the pyrophosphate, ZrP_2O_7, multiplied by 0·4632, gave the weight of ZrO_2.

Iron was determined in a known portion of the filtrate from the silica by precipitating as sulphide from ammonium tartrate solution. The sulphide was filtered, washed, and weighed in a porcelain crucible as Fe_2O_3.

Titanium might be determined on a separate portion of the original filtrate (remove all HF or HNO_3) colorimetrically or by titration with methylene-blue.

Aluminium was usually determined by difference.

C. M. M.

234. The De Roode–Perchloric Acid Method for Determining Potash. T. E. KEITT (*J. Ind. Eng. Chem.*, 1920, **12**, 276). —This was a preliminary report of work done by the author using the De Roode method of combustion. The procedure was as follows:—2·5 grams of the sample were placed on a 12·5 cm. filter paper and washed with boiling water into a 250 c.c. flask until the washings amounted to about 200 c.c. While hot, the solution was acidified with 5 c.c. of concentrated HCl. The sulphates were precipitated by adding a slight excess of normal $BaCl_2$ solution acidified with HCl, and when cold the solution was made up to 250 c.c. When the precipitate had settled, a 50 c.c. aliquot part, corresponding to 0·5 gram, was transferred to a porcelain evaporating dish, 30 c.c. of aqua regia were added, and the solution was evaporated to dryness on a hot plate. A second 30 c.c. of aqua regia were added and again evaporated to dryness. Finally, 10 c.c. of concentrated HCl and 20 c.c. of distilled water were added and evaporated to dryness. The residue was now dissolved in 20 c.c. of hot water, and 5 c.c. of perchloric acid (sp. gr. 1·12) were added. This was evaporated on a hot plate until copious fumes were evolved. When cold, a second portion of water and perchloric acid were added, and again evaporated until fumes appeared. After *cooling*, 20 c.c. of 95 per cent. alcohol were added, and then left to stand for about half an hour. The precipitate was collected either on a Gooch crucible or a tared filter paper and washed with alcohol containing 0·2 per cent. of perchloric acid. Finally, the precipitate was washed free from perchloric acid with alcohol ether (1:1). It was next dried at 120° for thirty minutes and, when cold, weighed. The potassium perchlorate was dissolved from the Gooch crucible with about 200 c.c. of hot water, and, to facilitate drying, the asbestos pad was washed with alcohol ether mixture, dried for thirty minutes, and weighed as before. The loss in weight was potassium perchlorate, which, multiplied by 0·34, gave the amount of potassium oxide.

A table was given which summarised the analytical data.

C. M. M.

235. Rapid Determination of Small Amounts of Copper by the Iodide Method. H. F. Bradley (*J. Ind. Eng. Chem.*, 1920, **12**, 800).—Copper was precipitated as sulphide and washed free from chlorides. (The author stated that it was not necessary to remove iron completely.) The precipitate was then moistened with a few drops of a strong neutral zinc nitrate solution free from chlorides, and ignited.

The residue of zinc oxide and cupric oxide was dissolved by warming with 1 c.c. of 1 : 2 hydrochloric acid. The solution was next neutralised with a 5 per cent. solution of potassium hydroxide, and then acidified with acetic acid. A little phosphate solution was also added to prevent the action of iron. Finally, 2·5 grams of solid sodium iodide were added, and the solution titrated as usual.

The author stated that the copper sulphide in the first place should not contain more than 0·05 gram of copper. C. M. M.

236. The Use of Cupferron in Quantitative Analysis. G. E. F. Lundell and H. B. Knowles (*J. Ind. Eng. Chem.*, 1920, **12**, 344).—In this paper the authors presented a review of the literature dealing with the use of cupferron (the ammonium salt of nitrosophenylhydroxylamine, $C_6H_5 \cdot N \cdot NO \cdot ONH_4$) as a quantitative precipitant. These precipitates were salts in which the ammonium radicle of the reagent had been replaced by metals. In all cases cold solutions must be employed to prevent decomposition of the reagent into various organic substances, for example, nitrobenzene. Wash waters were always cold, and for iron precipitates the authors suggested a 5 per cent. (by volume) solution of ammonium hydroxide, and a 10 per cent. (by volume) solution of hydrochloric acid for titanium and zirconium precipitates. The ordinary procedure was to ignite the precipitates to oxides, but caution must be exercised in the early stages owing to excessive liquefaction when wet precipitates were ignited and to the heavy liberation of gaseous products from dried precipitates.

Cupferron had been used successfully for the quantitative determination of copper, iron, titanium, zirconium, thorium, and vanadium, but many elements interfered with the determinations. The authors pointed out that in any given determination the partial or complete precipitation of the above six elements must be considered in addition to the following known interfering elements:—lead, silver, mercury, tin, bismuth, cerium, tungsten, uranium in the quadrivalent condition, silica, and in certain cases phosphorus, alkali salts, and alkaline earths when present in excessive amounts. This reagent should not be employed unless the qualitative composition of the material to be analysed was known, otherwise a most careful quantitative examination of the ignited and weighed cupferron precipitate should be made.

In certain separations, namely, iron from manganese and iron and titanium from aluminium and manganese, cupferron might be used advantageously. C. M. M.

237. Notes on the Preparation of Cupferron. D. R. Kasanof (*J. Ind. Eng. Chem.*, 1920, **12**, 799).—The author had obtained a good yield of phenylhydroxylamine from nitrobenzene by using amalgamated zinc dust.

The method of procedure was as follows. Sixty grams of nitrobenzene were thoroughly emulsified by vigorous stirring in 700 c.c. of water containing 30 grams of ammonium chloride. Eighty grams of zinc dust were amalgamated with a 2 per cent. solution of mercurous nitrate acidified with a few c.c. of nitric acid. After settling, the supernatant liquid was poured off and the zinc dust washed with water, under suction, until free from acid, when it was added in small quantities to the nitrobenzene emulsion. Vigorous shaking was essential, and the temperature should be kept at about 16°. After complete reduction, the zinc hydroxide was filtered off, the filtrate cooled to 0°, and sodium chloride added to saturate the volume of filtrate. A voluminous precipitate of phenylhydroxylamine was produced, which, after standing some fifteen minutes, was filtered off with suction and dried between filter paper. (This substance was a violent skin poison. Alcohol was the best remedial application.)

The damp phenylhydroxylamine was dissolved in 500 c.c. of ether and allowed to stand for twelve hours in a closed flask in contact with fused calcium chloride. The ethereal solution was then filtered, cooled to 0°, and saturated with dry ammonia. Sixty grams of cold, freshly distilled amyl nitrite were next added to the ethereal solution, when the vessel became filled with crystals of cupferron, which might be filtered off, washed with ether, and preserved in a glass-stoppered bottle in which a lump of ammonium carbonate was suspended. C. M. M.

238. A Convenient Method for the Preparation of a Hydrochloric Acid Solution of Cuprous Chloride for Use in Gas Analysis. Francis C. Krauskopf and L. H. Purdy (*J. Ind. Eng. Chem.*, 1920, **12**, 158).—In gas analysis, a solution of cuprous chloride in ammonium hydrate or hydrochloric acid was used for the absorption of carbon monoxide. Unless kept from contact with the air, it changed to the stable cupric salt, which was not an absorbent for carbon dioxide.

The present work was undertaken by the authors to ascertain whether a solution of cuprous chloride, produced by the action of stannous chloride on cupric chloride in hydrochloric acid solution, and hence containing stannic chloride, would be as efficient for the absorption of carbon monoxide as would be a solution of cuprous chloride formed by the reduction of cupric chloride by its action on metallic copper, and thus containing no other salts.

The conclusions arrived at were:—

1. That the efficiency for the absorption of carbon monoxide of a solution of cuprous chloride in hydrochloric acid was not impaired by the presence of stannic or stannous chlorides, even in relatively large amounts.

2. That for the preparation of cuprous chloride for absorbing carbon monoxide, a practical and efficient method consisted in dissolving cupric chloride in concentrated hydrochloric acid and reducing to cuprous chloride by the addition of stannous chloride.

The authors stated, further, that such a solution of cuprous chloride might be renewed from time to time, and prove as efficient as the original solution, by heating to 60° or 70° to drive off the carbon monoxide. If in this process a small amount of copper were oxidised and the solution were not colourless, a few drops of a concentrated stannous chloride solution would again reduce it.

C. M. M.

239. The McCrudden Gravimetric Calcium Method Modified. J. O. Halverson and J. A. Schulz (*J. Ind. Eng. Chem.*, 1920, **12**, 77).—The substitution of the volumetric asbestos Gooch method for the gravimetric procedure in the McCrudden calcium method was first employed by the authors in the determination of small amounts of calcium in biological and agricultural products.

High-grade ignited long-fibred asbestos was used, and this was digested at 60° to 70° for one hour with hot sulphuric acid (1 : 5). A few drops of potassium permanganate were added and the beaker kept covered. The material was then washed free from acid on a Buchner funnel. The Gooch crucible was prepared with some care, using the long, coarse fibres of asbestos first as a foundation, next the medium fibres to fill the interstices, and finally the fine sediment to form a compact top layer.

After the calcium oxalate had been precipitated it was filtered through a Gooch crucible and washed free from oxalate and oxalic acid. The precipitate and pad were then transferred with a small amount of hot water to an Erlenmeyer flask and titrated immediately at 65° with potassium permanganate solution, using sulphuric acid 1 : 5.

The authors found that this method gave almost identical results with the gravimetric procedure. The method described was rapid and the treated ignited asbestos did not tend to reduce potassium permanganate in the presence of 1 : 5 sulphuric acid at 65°.

C. M. M.

240. Substitutes for Platinum Wire in Bead and Flame Tests. C. C. Kiplinger (*J. Ind. Eng. Chem.*, 1920, **12**, 500).—The author held that the use of platinum wire in qualitative laboratory work was an important source of waste. It had been found feasible to use the "lead" from a lead pencil as a substitute for platinum wire for making bead tests. A stout piece of "lead" was held in the Bunsen flame by means of tongs until the end was red hot, when it was dipped in borax and returned to the flame. This drop constituted the bead, and the tests were made as usual. The reducing action of the carbon did not seem to interfere materially. The author had found the method described by

Ehringhaus very convenient when used in conjunction with the following device. A glass tube 15 cm. long and 6 mm. in internal diameter was bent at an angle of 45° 2 cm. from one end, and the latter held in the flame until the opening was reduced to 3 mm. in diameter. A small strip of filter paper was rolled tightly to fit the opening, and the longer arm of the tube was filled with the test solution, or with dilute hydrochloric acid if a powder was to be tested on the paper. The burner was supported horizontally, and the upper end of the paper wick was placed so that it barely touched the bottom portion of the flame. The salt solution was vaporised, and coloured the flame with the minimum consumption of paper.

The author also stated that a clean iron nail was of value in these tests, as, in general, the spectra of the iron salts did not interfere. C. M. M.

241. The Removal of Ammonium Sulphide in Qualitative Analysis. F. Feigl (*Zeitsch. analyt. Chem.*, 1920, **59**, 12).—The ordinary method of removing ammonium sulphide by acidifying and boiling off the hydrogen sulphide often resulted in the formation of colloidal sulphur, and probably in the production of some sulphuric acid, owing to oxidation of the sulphur. The formation of sulphuric acid interfered with tests for the elements of group IV. These difficulties could be avoided by adding to the solution containing the ammonium sulphide a slight excess of lead hydroxide, warming the mixture, and then filtering. The filtrate obtained was quite clear and free from lead and sulphur.

F. W. H.

242. The Determination of Potassium as Perchlorate. G. P. Baxter and M. Kobayashi (*J. Amer. Chem. Soc.*, 1920, **42**, 735).—The authors recommended the use of a platinum sponge crucible, absolute alcohol, and a low temperature (0°) in washing, the solution of the precipitate in water, and a further evaporation during the course of washing. For the washing of the potassium perchlorate after the sodium perchlorate had been extracted with alcohol containing perchloric acid, a saturated solution of potassium perchlorate in alcohol containing perchloric acid at the temperature of washing was also recommended. The saturated solution should be made by dissolving the requisite amount of potassium perchlorate in a hot concentrated solution of perchloric acid in water and adding the solution to absolute alcohol. F. W. H.

243. The Separation of Chromium and Manganese. M. Herschkowitsch (*Zeitsch. analyt. Chem.*, 1920, **59**, 11).—To the solution containing the manganese and chromium as permanganate and chromate, respectively, ammonium sulphate was added, and then excess of ammonium hydrate. The mixture was heated on a water-bath for some hours and the whole of the manganese precipitated. The manganese precipitate was filtered off, washed with a 5 per cent. solution of ammonium sulphate, finally washed with hot water, ignited to Mn_3O_4, and weighed as such. The filtrate contained the chromate unchanged. F. W. H.

244. The Separation of Zirconium and Titanium as the Phosphates. J. Brown and H. T. Madden (*J. Amer. Chem. Soc.*, 1920, **42**, 36).—The solution containing the sulphates of zirconium and titanium was rendered acid to the extent of from 1 to 2 per cent. of free sulphuric acid by volume. Excess of hydrogen peroxide was added and the zirconium phosphate precipitated by the addition of excess of sodium or ammonium phosphate. After standing overnight, any titanium in the zirconium phosphate, after filtering and washing, was removed as in the original Hillebrand method, and the filtrates were added to the main filtrate from the zirconium precipitation.

The combined filtrate containing titanium was heated to remove hydrogen peroxide, adjusted so as to contain 2 per cent. excess of sulphuric acid by volume, and then excess of sodium or ammonium phosphate was added and the solution allowed to stand one hour. After filtering and washing, the phosphate was converted to titanium oxide and weighed as such, since it was found that the titanium phosphate precipitate was of variable composition.

F. W. H.

245. The Use of Iridium Crucibles in Chemical Operations. W. Crookes (*Proc. Roy. Soc.*, 1908, **80**, [*A*], 535).—Iridium was as hard as steel, and a crucible was almost unaffected by any mechanical treatment that could reasonably be applied to it. The author subjected an iridium crucible to a large number of exacting tests, and there was no loss in weight or apparent action on the metal, when a platinum crucible would have been affected badly. Nickel, gold, iron, and zinc were melted in it and poured off with no injury to the crucible. Copper melted in it for some time made it brittle whilst hot, but if the copper was burnt off at a high temperature the iridium was undamaged.

A rhodium crucible was found to be nearly equally resistant, and as the weight would be only one-half of that made of iridium the cost would be less. J. R. C.

IX.—Machinery for the Working of Glass.

246. Bottle-blowing Machine. Michael J. Owens (U.S.A. Pat., November 25th, 1919, No. **1322726**. Filed October 26th, 1914, No. 868730).—The invention consists of detailed improvements in the Owens machine, particularly that form of the machine described in U.S.A. Pat. No. 1185687. The improvements consist of (1) a steadying device for supporting the parison and preventing it from swinging, and also for avoiding the shear mark caused by returning the cut-off knife in position, as at present; (2) a vertically rising blow mould; and (3) the use of compressed air for opening and closing the blow moulds.

On each arm of the machine a bracket, K (Fig. 125), is secured below the blow mould, and this bracket carries two air cylinders, one of which, L, raises and lowers the blow moulds, and the other, L', has a bottom plate, Q, secured to the upper end of its piston rod, N'. After a charge has been sucked into the parison mould, D, from the rotating tank, F, the shears cut off the thread of metal and is then withdrawn. The bottom plate, Q, is then raised, and closes the bottom of the parison mould, as shown in Fig. 127. The plate, Q, remains in place when the parison mould is open, and thus prevents the parison from swinging while the blow mould is being raised and closed about the parison. The halves of the blow moulds are connected by links, T' (Fig. 126), to cranks, T, which are rotated by racks, v, v', formed on the piston rods of air cylinders, V', secured to the slides of the blow moulds. By the use of air to operate the moulds, the danger of breakage due to chilled glass getting between the sections of the mould is avoided. G. D.

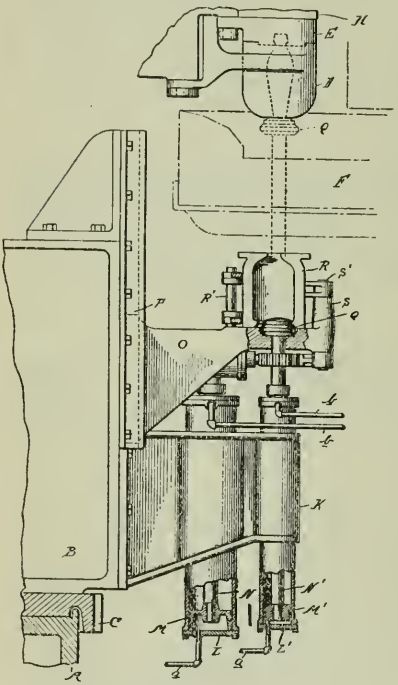


FIG. 125.

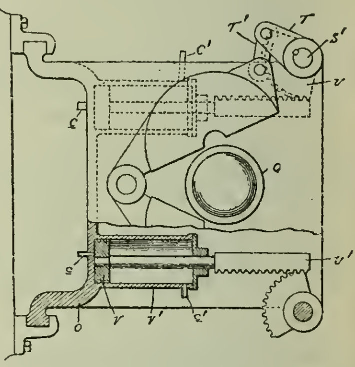


FIG. 126.

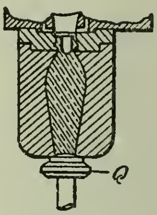


FIG. 127.

247. Semi-automatic Bottle-blowing Machines. JOHN RAU (U.S.A. Pat., December 16th, 1919, No. **1325331.** Filed January 12th, 1917, No. 142023).—The specification describes the parison-forming mechanism of a semi-automatic bottle-making machine in which the mould table, 15, is rotated step by step by hand, and the blow-head, 73, for admitting air for packing the metal into the parison mould, is lowered on to the moulds by hand. The invention lies chiefly in the construction of a valve, 27, which controls the air supply. The upper end of the stem, 26, of this valve locks the table against rotation, and it is depressed by means of a pedal, 32, to free the table. Thus the action of locking or unlocking the table controls the air for packing the metal into the mould, for operating the plunger, 66, which forms the mouth of the bottle, for operating the mould cover, 91, and for blowing-up the parison in the mould against this cover. The construction of the valve and the arrangement of the air pipes are described in detail in the specification.

G. D.

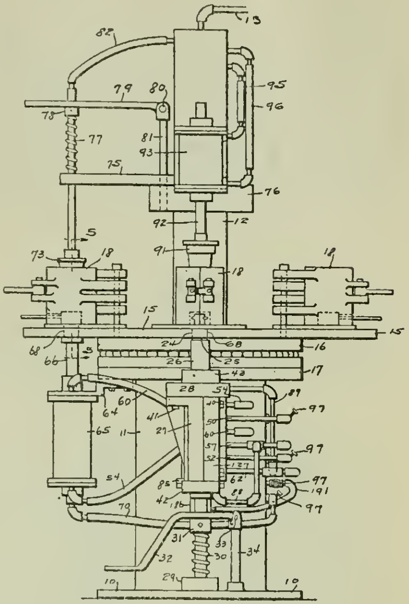


FIG. 128.

248. Improvements to Bottle-blowing Machines. KARL E. PEILER (Assignor to HARTFORD-FAIRMONT CO.) (U.S.A. Pat., March 12th, 1918, No. **1259281.** Filed July 3rd, 1915, No.

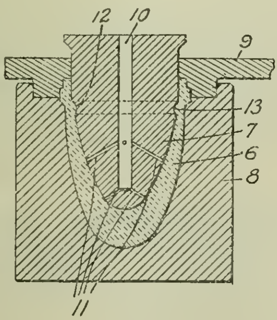


FIG. 129.

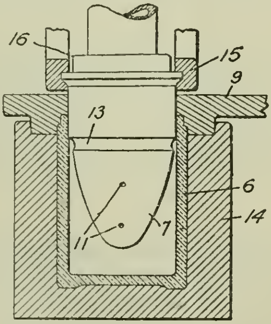


FIG. 130.

37847).—In order to avoid the use of a two-part ring mould, particularly with automatic or semi-automatic machines, the press plunger, Fig. 129, which forms the parison, has a shallow, circumferential groove, 13, near its base, and is also pierced with air passages, 10, 11. Part of the metal of the parison is forced into the groove, 13, and gives sufficient anchorage to enable the parison to be transferred to the finishing mould by means of the plunger. When the parison is blown out in the finishing mould, as shown in Fig. 130, by air admitted through the passages, 10, 11, the temporary shoulder formed inside the parison disappears and the plunger can be withdrawn from the finished article. The plunger can also be used with machines which gather by suction. G. D.

249. Making Vacuum Bottles. HARRY BASTOW (U.S.A. Pat. February 12th, 1918, No. **1256427**. Filed March 14th, 1917, No. 154721).—The specification describes a process of making vacuum vessels by pressing.

The mould comprises a base, 10 (Fig. 131), with an upstanding core, 12, a two-part body, 14, and a ring mould, 20, with a depending annular core, 22, which at one or more places, 23, is extended to meet the core, 12. After removal from the mould, the blank, of the shape shown, is "warmed in," and the walls and bottom are closed in by hand to form a vessel of the shape shown in cross-section in Fig. 132. G. D.

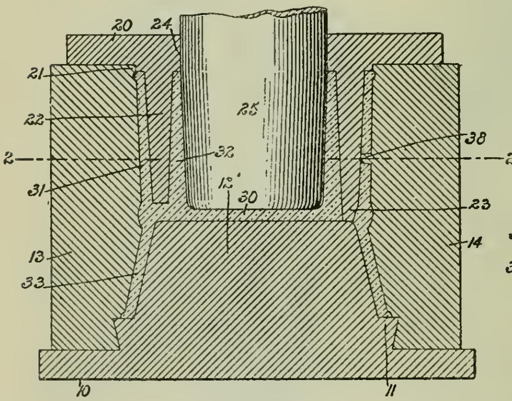


FIG. 131.

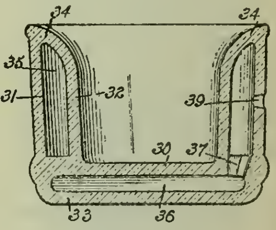


FIG. 132.

250. Mould for Bottle-blowing Machines. EDWARD S HUTTON (U.S.A. Pat., January 15th, 1918, No. **1253246**. Filed February 12th, 1916, No. 77991).—The parison mould and finishing mould of a bottle-blowing machine are arranged in one framework and contiguous to one another, and the halves of both moulds are opened simultaneously, so that the parison is moved quickly from one mould to the other and undue chilling is avoided. The moulds are shown in end elevation in Fig. 133 and in side elevation in Fig. 134. They are arranged side by side, and the halves are screwed to cross-frames, 14, 15, which are mounted in guideways formed by bars, 13. The bar 15 is stationary in the guides, but the bar 14 can be moved along the guides by a tube, 18, movement of which thus opens or shuts both moulds. The frame, 12, to which the bar, 13, is secured is mounted on trunnions, and can be oscillated by a crank, 20, to invert the moulds. The upper ends of the corresponding mould halves are connected by a guideway, 23, and a "lift-over," 25, carrying the halves of the ring mould, slides in this guideway. A blow tube, 30, connected by a tube, 31, with the tube 18 is also carried by the lift-over.

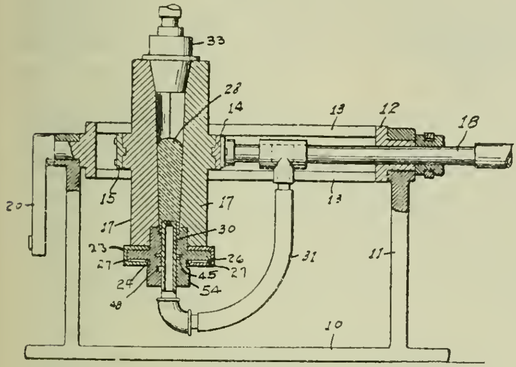


Fig. 133.

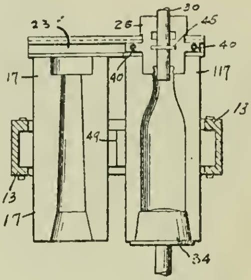


Fig. 134.

In use, the "lift-over" is moved to bring the ring mould over the parison mould, the moulds are closed, and are then inverted, as shown in Fig. 133. Metal is then dropped into the mould and is packed down into the ring mould by air admitted from a blowhead, 33. The parison is then blown by air admitted to the tube, 30, the blowhead, 33, removed, and the moulds inverted. The mould halves are next separated by sliding the tube, 18, and the "lift-over" is moved along the guideway, 23, so that the parison is suspended in the finishing mould, as shown in Fig. 134. The moulds are closed, a bottom, 34, is moved into place, and the parison is blown in the finishing mould. The corresponding halves of each mould could be made in a solid piece, but it is preferable to keep them separate in order to facilitate cooling. G. D.

251. An Automatic Taking-off Device for Glass-blowing Machines. H. C. Fentress (U.S.A. Pat., April 6th, 1920, No. **1336028.** Filed February 21st, 1919).—This automatic taking-off device consists of a pedestal, 19, fixed vertically in front of the blowing-machine table, 17 (Fig. 135). On this pedestal is mounted in a horizontal plane an annular bearing concentric with the post, 19. Journalled to the post, 19, and carried by ball bearings in the annular rim, is a turntable, 23. This turntable has peripheral gear teeth, 25, meshing with similar teeth, 13, on the table of the blowing machine. Mounted above the turntable, and held in position by the studs, 28, and binding nuts, 31, is an annulus, upon which are carried the taking-off jaws, each of which consists of a pair of levers, 32 and 33, connected together in crossed relation by the pivot, 34. The lever, 32, is slidally mounted, but otherwise fixed by the set screw, 36, while the lever, 33, is movable and is operated by the tripping cam, 41, cut on the upper end of the post, 19, and the retractile spring, 42, which keeps the lever, 40, up to the cam, 41.

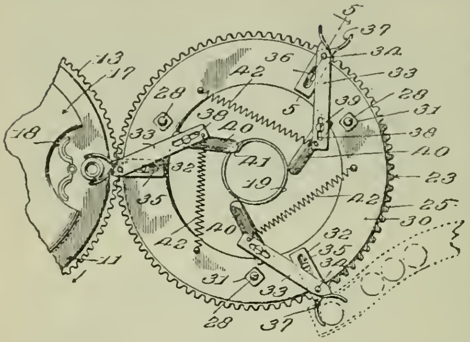


Fig. 135.

In operation, the turntable, 23, moves along with the table, 11, and the take-off jaws are set at intervals, so as to synchronise with the bottle moulds. The action of the tripping piece, 40, and the tripping cam, 41, then causes the jaws to grasp the bottle, and, as the table rotates, to carry it round and deposit it on a conveyor or into a receiver.

S. E.

252. Ring Mould for Bottle-making Machine. W. Stender (U.S.A. Pat., March 19th, 1918, No. **1259800**. Filed April 2nd, 1917, No. 159053).—Relates to a ring mould chiefly designed to prevent the formation of fins on the bottle mouth. The mould is made in halves, 8, 9 (Fig. 136), as usual, and the complete mould is of conical shape, so that it fits into a conical recess, 6, in the block, 5, that holds the mould. Thus when moulding pressure is applied to the mould, the halves are forced tightly together, and the formation of seams, resulting in fins, on the bottle neck is prevented. The plug, 14, slides in the bore, 7, of the block, 5, and has a conical portion, 16, which fits into a conical recess in the ring mould. The plug and the inner surface of the mould are shaped to form a bottle mouth,

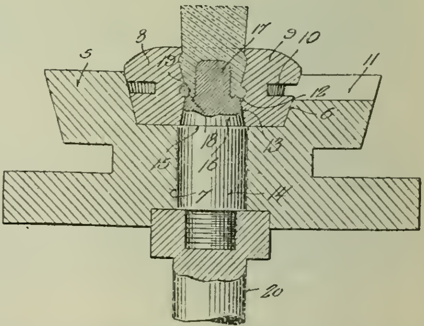


Fig. 136.

having an annular groove suitable for the capsule closure, described in U.S.A. Pat. No. 1191194. G. D.

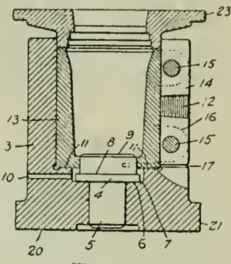


FIG. 137.

253. An Improved Mould. KARL E. PEILER (Assignor to HARTFORD-FAIRMONT Co.) (U.S.A. Pat., March 12th, 1918, No. **1259280**. Filed March 17th, 1914, No. 825237).—A mould for either hand-working or for machine consists of a body, 3 (Fig. 137), of the usual size and shape, and a liner, 13, which constitutes the mould proper. Thus one set of bodies will serve for moulds of many different patterns, and a liner when worn can be replaced cheaply. G. D.

254. Apparatus for Transferring Glass to Moulds. R. LA FRANCE (Assignor to the Owens Bottle Machine Co.) (U.S.A. Pat., February 24th, 1920, No. **1331511**. Filed June 17th, 1918).—The object of this invention is to guide formed gobs of glass into the moulds of a continuously moving machine. An oscillating transfer device, 16 (Fig. 138), in the form of a trough is the means used to guide the glass into the moulds, 17, on the moving table of the machine. The chute, 16, is mounted on a vertical rocking shaft, 19, to which is secured an arm, 20, carrying a cam roll, 21, held by a spring (not shown) against the cam, 22, which is mounted on the cam shaft, 12. The cam, 22, is so formed that it oscillates the trough, causing it to move in the same direction as the mould, 17, and in register therewith, while the mould is passing the charging station.

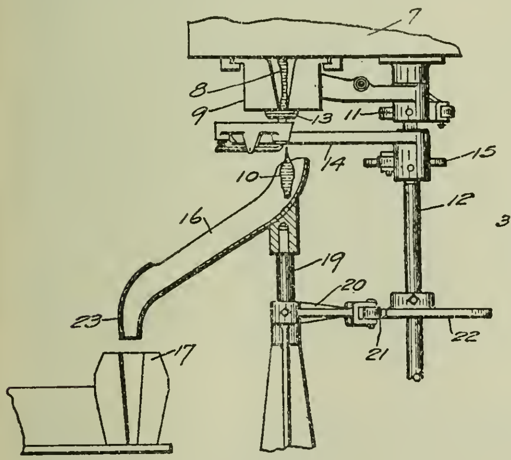


FIG. 138.

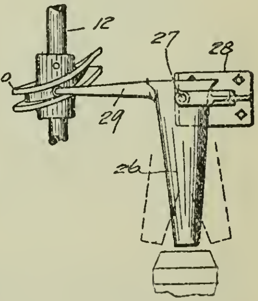


FIG. 139.

In a modified form (Fig. 139) the transfer device is in the form of a funnel, 26, pivoted on a bracket, 28, so as to swing about a horizontal axis, 27. An arm, 29, extending horizontally from the upper end of the funnel engages a cam, 30, on the shaft, 12. This cam is so formed as to swing the lower end of the funnel in an approximately horizontal direction, the limit of movement being indicated by the broken lines. S. E.

255. Apparatus for Transferring Charges of Glass. J. M. Lents (Assignor to the Owens Bottle Machine Co.) (U.S.A. Pat., February 24th, 1920, No. **1331512**. Filed May 20th, 1918).—This invention relates to means for transferring charges of molten glass from a flowing device or gob-forming apparatus to two forming machines. Molten glass is allowed to flow into a preliminary gob-forming or accumulating device, and then when ready is allowed to fall into the transfer cup, 10 (Fig. 140), which is carried on a rocking arm, 11, fixed on the shaft, 12. The shaft is journalled in a standard and rocked by means of a cam, 14, carried on a continuously rotating shaft, 15. An arm, 16, fixed to the rocking shaft carries a cam roll, 17, which is held against the cam by a spring, 18. The cam is so formed that the cup, 10, is held stationary beneath the flow opening while it receives a charge, and then swings alternately to the right and the left to transfer the charges in turn to the two machines. The cup, 10, is made in sections carried on arms, 28, which are mounted on pivots, 29, and have intermeshing gears, 30. Normally, the cup is held closed by the spring, 31. As the cup comes over a mould in the discharging position, one of the arms, 28, engages a stop, 32, thus opening the cup, as indicated by the broken lines. S. E.

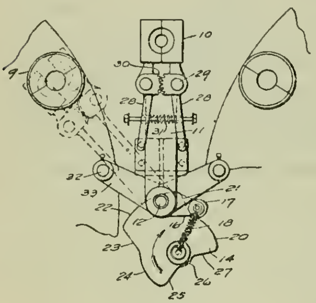


Fig. 140.

256. Removing Glass from Furnaces. E. T. Ferngren (U.S.A. Pat., June 1st, 1920, No. **1342042**. Filed September 4th, 1913, No. 788174).—When glass is withdrawn from a furnace by mechanical means, for example, by suction moulds, the removing tool dips into the mass of glass each time at substantially the same point, thus causing a very appreciable chilling at that point. When the gathering is done by hand this source of trouble does not arise if the worker does not dip his tool into the surface of the glass at the same place a number of times in succession.

If the surface layer of the glass be moved in between the successive dips of a mechanically operated tool, then no local chilling can occur, and each gather will consist of fresh, uninjured glass. This movement of the surface can be obtained by allowing the glass to overflow from the fining chamber into a trough with a slight downward inclination, from which the glass is gathered. This trough preferably opens into an enlarged receptacle adapted to receive such glass as is not removed from the trough in flowing through. The glass flowing into the collecting receptacle may be returned to the furnace in any desired manner.

S. E.

257. Means for Transferring Molten Glass to Moulds. L. D. SOUBIER (Assignor to the Owens Bottle Machine Co.) (U.S.A. Pat., February 24th, 1920, No. **1331536**. Filed July 8th, 1918).—A continuously rotating bottle machine is more rapid in operation than an intermittent one, but as the moulds of such a machine are not stopped at the charging point, special provision must be made to guide the glass into the moving moulds. This may be effected in this invention, in which a series of inclined troughs, 15, are mounted on a vertical axis. Each trough is pivoted to the bracket, 17, which is mounted on the continuously rotating vertical shaft, 18. The path of travel of the discharging end of the troughs is controlled by the stationary cam, 20, mounted on a standard, 30. The guides have cam rollers, 21, which are held in position against the cam surface by tension springs, 31. The cam, 20, is formed with a re-entrant portion, the curvature of which is substantially concentric with the path of the moulds, thus the discharge opening of each chute remains in register with the corresponding mould while travelling through an arc of some length. The cam, 20, is so shaped that it allows the chutes to drop into a vertical position when they have passed over the mould table, thereby allowing the apparatus to be used in a limited space.

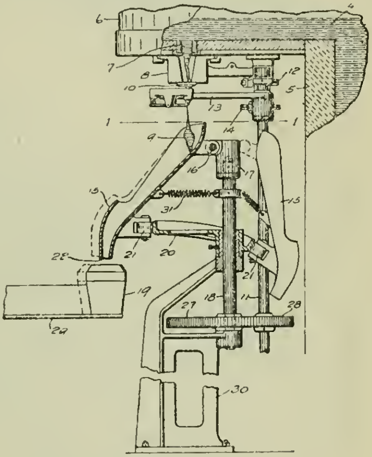


FIG. 141.

S. E.

258. Mechanism for Delivering Glass. R. NETTER U.S.A. Pat., September 2nd, 1919, No. **1314691**. Filed November 12th, 1915, No. 61015).—In Fig. 142 *A* indicates the usual delivery end of a tank furnace, *B* an auxiliary spout, *C* the cut-off mechanism, and *D* the mould table. Beneath the opening, 2, in the delivery end, *A*, is a circular chamber, 5, intended to hold the head, 7, of the auxiliary spout and allow it to rotate. The spout, *B*, is pivoted between the forked end, 12, of an extension of the central column, 8, of the mould machine, and its height may be adjusted by the set screw, 14. This spout is preferably comprised of a refractory lining, 15, and a supporting casing, 16, and is arranged so that its lower end moves along the same path as the moulds. Attached to the lower end of the spout is a water-cooled plate, 17, to which the cutting members are attached. Mounted on the central column, *A*, is a spring, 30, which, operating against the extension, 31, keeps the spout when it is free in its initial position against the stop, 32.

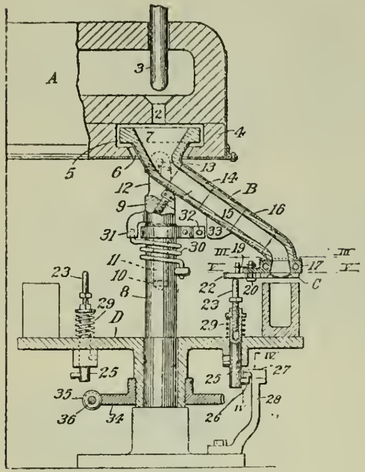


FIG. 142.

The operation of the device is as follows. Glass flows from the tank shoe, *A*, through the opening, 2, into the spout, *B*, which is held by the spring, 30, against the projection, 32, until a mould comes underneath the lower end of the spout. The member, 23, then comes against an extension, 22, of the cutting mechanism, and, pressing against it, opens the cutting shells, thus allowing the glass to fall into the mould. The member, 23, by bearing against the extension, 22, also carries the spout along with it for some distance before the cutting shells are released and brought together again by a spring. When the stream of glass has been severed, the spring, 30, brings the spout back to its initial position ready for the next mould coming along.

The glass in the spout may be maintained in a molten condition by suitable heating means. S. E.

259. Flowing Molten Glass. J. WHITTEMORE (Assignor to the Owens Bottle Machine Co.) (U.S.A. Pat., July 15th, 1919, No. **1310225**. Filed December 26th, 1918, No. 268256).—The primary object of this invention is to provide means for reheating the severed end of a mass of glass that has been severed and chilled by a cutter, and at the same time to reheat the whole mass of glass and prepare it for entering the mould.

Just below the exit from a flow chamber, a cap with an inner refractory lining is provided. This lining is heated by a coil of resistance wire, and in turn serves to heat the gob of glass falling from the furnace extension. The glass is prevented from coming into actual contact with the heated lining by means of jets of hot air supplied through perforations in the walls of the cup. Suitable mechanism is provided for automatically dropping the cup away from the glass and swinging it to one side after the glass has been sufficiently reheated. The cam-operated shears then sever the stream of glass and allow the gob to drop into the mould.

S. E.

260. Apparatus for Delivering Mould Charges from Glass Furnaces. S. Davidson and A. L. Schram (Assignors to Schram Glass Manufacturing Co.) (U.S.A. Pat., April 27th, 1920, No. **1338214**. Filed July 21st, 1917, No. 182046).—The aim of the inventors is to provide means for separating and dropping charges of molten glass into moulds under the action of gravity alone, and without any chilling of the depending end of the stream of glass. The chilling of the glass at the point of severance is avoided by having the molten glass above the shears drawn upwards immediately it has been cut, so that at no time do the shears support the stream of glass.

As shown in Fig. 143, the furnace bed, 13, is apertured to receive the bushing, 14, through which the orifice, 15, extends. The mouth of the orifice, 16, is closed when the apparatus is at rest by the lower face, 18, of the plunger, 19. The plunger is mounted through the aperture, 32, in the furnace top, and is operated through the lever, 36.

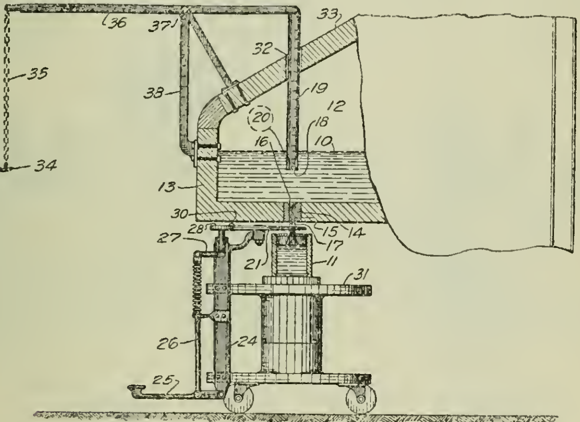


Fig. 143.

When a mould is in position to receive a charge the plunger is raised, thus permitting a stream of glass to flow through the orifice, 15. When sufficient glass has flowed through the orifice, the shears, 21, are actuated, severing the stream of glass just below the mouth, 17. As soon as the shears have made the cut, the plunger, 19, begins to move upward, and in so doing pulls the column of glass, 23, with it, so that it becomes reheated by contact with the mass of glass in the furnace. By the time the downward movement of the plunger has begun, the glass of the column, 23, has thoroughly mixed with the body of glass, and the discharge of a new mould charge has begun under the action of gravity. It is found that the upward movement of the glass responds more certainly to the action of a plunger having a cupped cavity in its lower face.

S. E.

261. Means of Charging Glass Moulds. J. F. Rule (Assignor to the Owens Bottle Machine Co.) (U.S.A. Pat., February 24th, 1920, No. **1331528**. Filed July 26th, 1918).—The object of this invention is to provide a mechanism comprising a receptacle in which glass is accumulated and formed into gobs, and which can be moved from a filling to a discharging position, and thereby serves as a transfer device for transferring gobs to the moulds.

A continuous stream of glass flows through an opening, 7 (Fig. 145), in the bottom of the furnace extension, 6, and through a compartment, 8, into the transfer cup, *C*. The cup, *C*, is carried on an arm, 11, mounted to rock on a shaft, 12, by means of which the cup can swing to its discharge position above the mould, 10. The transfer cup, *D* (Fig. 144), is similarly mounted, and can swing over the mould, 10, on table *B*. Each of these transfer cups is built up in sections made to swing on pivots, 14, permitting the sections to separate and drop their charges into the moulds. As the cup swings to its discharging position, a stop, 17, in the path of the arm, 16, separates the cup sections against the action of the spring, 15. Intermeshing gears, 18, ensure equal movement of the cup sections about their pivots.

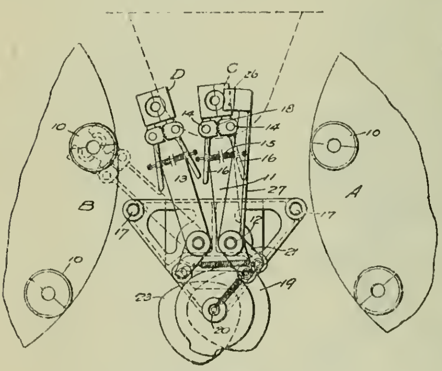


Fig. 144.

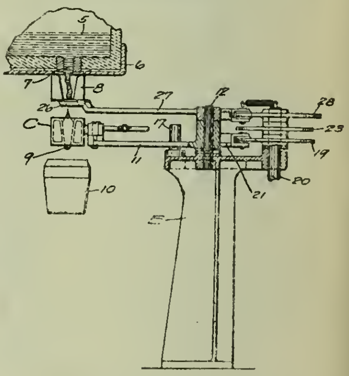


Fig. 145.

The cup-carrying arm is rocked by a cam, 19, on a continuously rotating shaft, 20. The cam is so shaped that during nearly one-half revolution the cup, *C*, is held below the opening, 7, and is then swung into position over the mould, 10, and held there until the gob has dropped into the mould. The movements of the cup, *D*, are controlled by a similar cam, 23. These cams are so arranged that as soon as one cup begins its travel towards the mould table it is immediately replaced by the other cup. A knife, 26, forms a temporary bottom for the receptacle, 8, during the short interval in which one cup is being replaced by the other. S. E.

262. Making Globes and Shades. FREDERICK W. STEWART (U.S.A. Pat., March 12th, 1918, Nos. **1259156** and **1259157**. Filed June 20th, 1916, Nos. 104668 and 104669).—Relates to the method of making globes, shades, and other open-ended hollow articles by pressing and blowing, the lower end portion of the article when taken from the mould being cracked-off and ground.

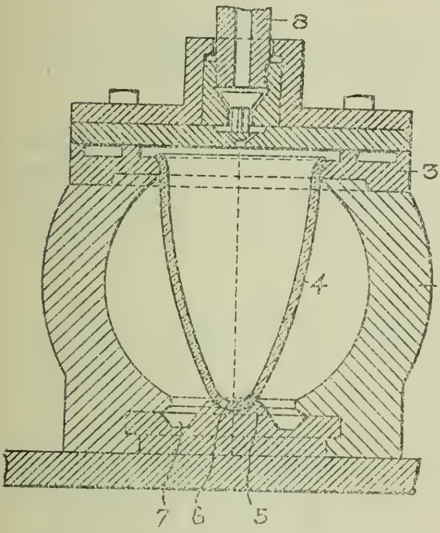


FIG. 146.

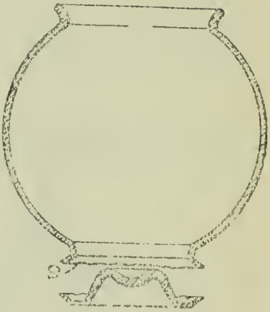


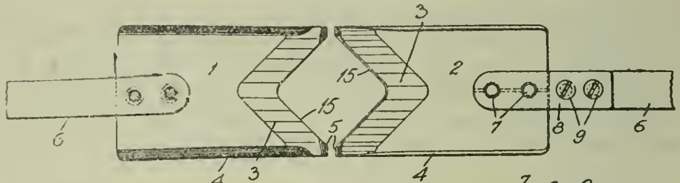
FIG. 147.

According to the invention, the bottom of the finishing mould has a raised central boss, 5 (Fig. 146), with a concave seating, 6, which supports the lower end of the parison, 4, as shown, when it is placed in the mould. When the parison is blown out to fill the mould, the part that fills the recess, 7, is thinner than the wall of the globe proper owing to the chilling of the end of the parison by resting in the seating, 6. The bottom can now be removed by tapping it from the inside, when it breaks away along the thin part, 9, as shown in Fig. 147. G. D.

263. Shearing Hot Metal. W. A. LORENZ (Assignor to The Hartford-Fairmont Co.) (U.S.A. Pat., December 30th, 1919, No. **1326460**. Filed March 27th, 1917, No. 157668).—The invention consists of shears for severing a stream of molten glass into drops. The blades, 1, 2 (Fig. 148), are stamped from relatively thin sheet steel, and are provided with V-shaped cutting edges, 15. The points, 5, of the V-shaped notches are bent as shown in Fig. 149, in order to ensure that the blades will ride past each other when they come together for cutting. One of the blades is secured firmly to its shank, while the other is free to rock slightly in its shank. The purpose of this arrangement is to ensure that the cutting edges of the two blades remain in contact with one another during cutting. The blades are stiffened by bending over the edges, 4.

G. D.

Fig. 148.



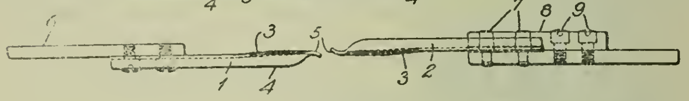


Fig. 149.

264. Drawing Glass. Clarence P. Byrnes (U.S.A. Pat. December 30th, 1910, No. **1326571**. Filed February 4th, 1914, No. 816507).—The invention consists in drawing two or more cylinders simultaneously, one within the other, in order to increase output. It is stated that the method may be used to produce double-walled vacuum-jacketed receptacles. Two concentric baits, 2^a, 3^a (Fig. 150), are employed, and air is admitted to the cylinders either through the baits or, as shown, through tubular bosses, 17, in the pot. A water-cooled box, 18, projecting into the inner cylinder is used to cause setting of the glass of the inner cylinder, and a water-cooled jacket, 15^a, surrounding the outer cylinder may be used.

G. D.

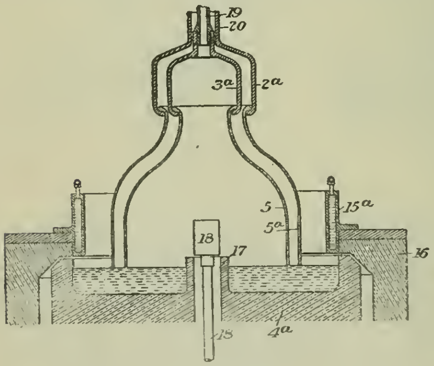


Fig. 150.

265. Drawing Glass Sheets. Harry G. Slingluff (Assignor to Pittsburg Plate Glass Co.) (U.S.A. Pat., January 1st, 1918, No. **1251932**. Filed May 16th, 1916, No. 97797).—The invention relates to the drawing of glass in sheet form and to means for preventing the pulling-in of the edge of the sheet. The drawing member consists of a block, 4 (Figs. 151 and 152), floating on the metal, 3, and provided with an elongated slot, 15, through which the sheet, 16, is drawn. Drawing-blocks, 5, rest in the ends of the slot, 15, and the height of each block above the member, 4, is adjustable by means of a refractory black, 7. Each block, 5, has an extension or shelf, 8, having its upper face grooved, and this groove communicates by an opening, 10, with vertical openings, 11, 12, pierced through the block.

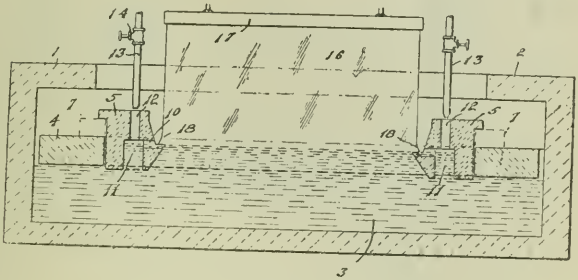


FIG. 151.

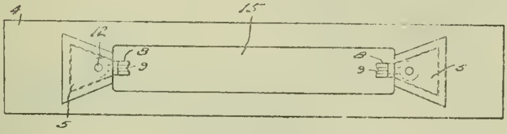


FIG. 152.

In use, the blocks, 5, are adjusted so that the edges of the sheet are drawn from the grooved upper faces of the extensions, 8, as shown in Fig. 152. If the sheet tends to pull in its edges, jets of air from pipes, 13, are directed into the openings, 12, thus cooling and stiffening the metal from which the edges of the sheet are drawn.

G. D.

266. Drawing Glass Cylinders. CLYDE S. ROBB (U.S.A. Pat., February 12th, 1918, No. **1256260**. Filed January 16th, 1917, No. 142622).—The specification describes an apparatus for drawing glass cylinders. The pot, 2, is of usual construction, and is fitted with a hollow central standard, 6, for admitting air to the interior of the cylinder. The bait, 8, is cylindrical, and telescopes on to a base, 8, which is fixed to a vertical guide rod, 11, sliding through bearings, 12. Lugs, 23, on the bait are engaged by hooks, 24, on cables, 25, which are drawn upwards by a motor, 16. The motor is situated in a cage, 13, which runs on overhead rails, 15. In use, a cylinder is drawn until a latch, 20, engages a notch, 19, in the rod, 11. The cylinder is then severed at its lower end and the bait is lowered until it is free from the base, 9, and the cylinder is then removed. During drawing, the cylinder is surrounded by a rectangular framework, 29, having louvered sides, which are adjustable like the slats of a venetian blind. By this means, the circulation of air along the cylinder can be regulated. A protecting cover, 33, of refractory material, and fitted with gas burners, 35, is arranged so that it can be swung over the pot when required.

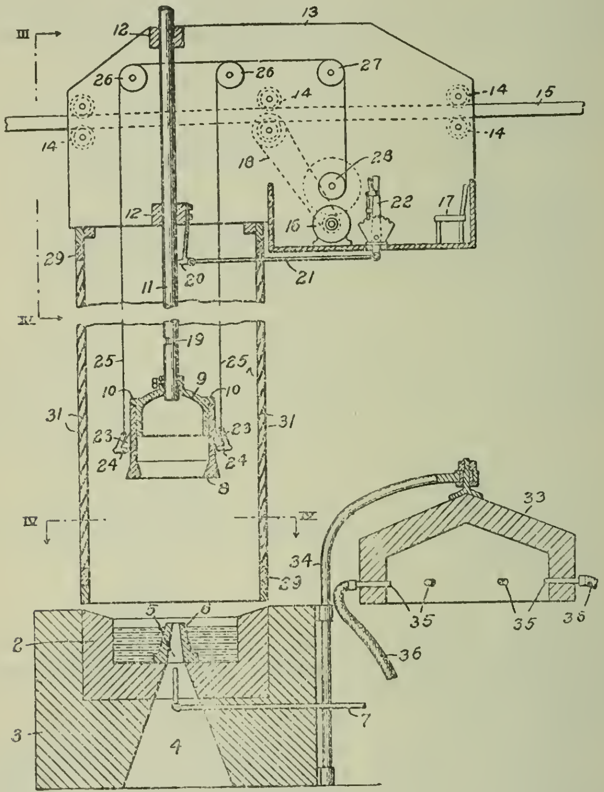


FIG. 153.

G. D.

267. Drawing Sheet Glass. HALBERT K. HITCHCOCK (U.S.A. Pat., December 16th, 1919, No. **1324965**. Filed January 2nd, 1918, No. 209867).—Sheet glass is made by drawing the metal upwards in a flat strip or sheet, 7 (Fig. 154), through a longitudinal slot in a refractory member, 1, supported above the body of molten metal, 3. The drawing-slot is partly filled with a refractory bar, 6, the distance of which below the surface of the metal may be adjustable. This bar serves as a shield to protect the sheet, 7,

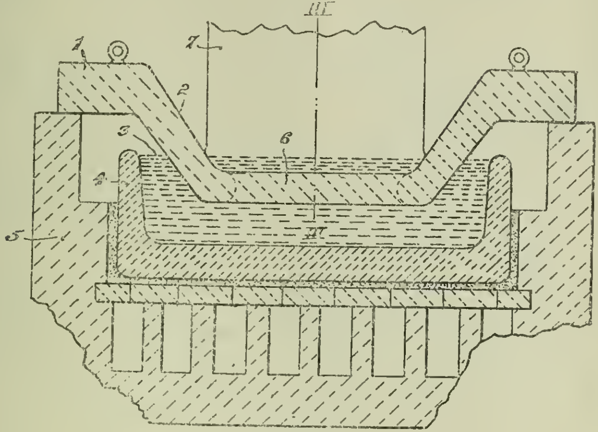


FIG. 154.

from the heat radiated from the hot metal below the drawing-slot.
G. D.

268. Drawing Glass Cylinders. OCTAVE C. NATALIS (U.S.A. Pat., January 1st, 1918, No. **1251561**. Filed February 28th,

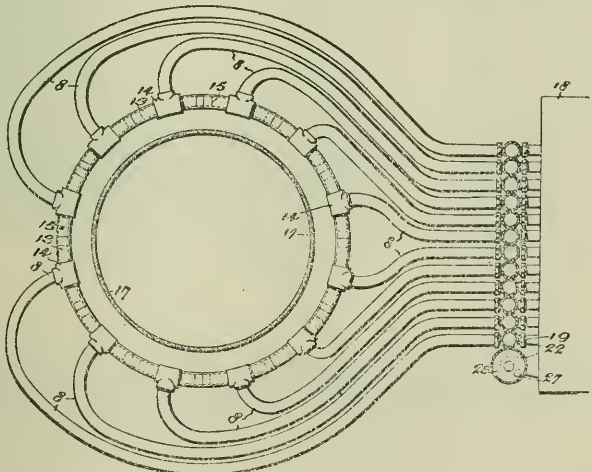


FIG. 155.

1917, No. 151474).—In order to overcome variations in the thickness of a cylinder as it is being drawn, means are provided for directing either a hot or a cold blast on the cylinder, the temperature of which may be varied at different points around the circumference of the cylinder. The device consists of a ring, 13, surrounding the cylinder near the point at which it is drawn from the tank, and provided on its inner side with perforations or ports for the emission of the blast. The ring is made up of separate sections, each connected by a pipe, 8, with a tank, 18. Each pipe has its own control valve, 19, all of which are geared together and with a master gear, 26. Thus the valves can be operated together, but each valve can also be operated separately, in order that the blast from any section of the ring, 13, may be varied. The ring may be supplied with air for a cold blast or with gas that can be lighted at the ports for a hot blast. G. D.

269. Drawing Glass Cylinders. Harry G. Slingluff (U.S.A. Pat., January 1st, 1918, No. **1251931**. Filed January 20th, 1914, No. 813197).—A tank from which cylinders are drawn is provided with inwardly projecting deflecting or baffle walls, 12, 13, between the melting end, 3, and the drawing end, 5. These walls, projecting into the metal, prevent the accumulation of impurities in the nearer drawing openings, 6, and also tend to equalise the temperature of the metal in all the drawing openings. G. D.

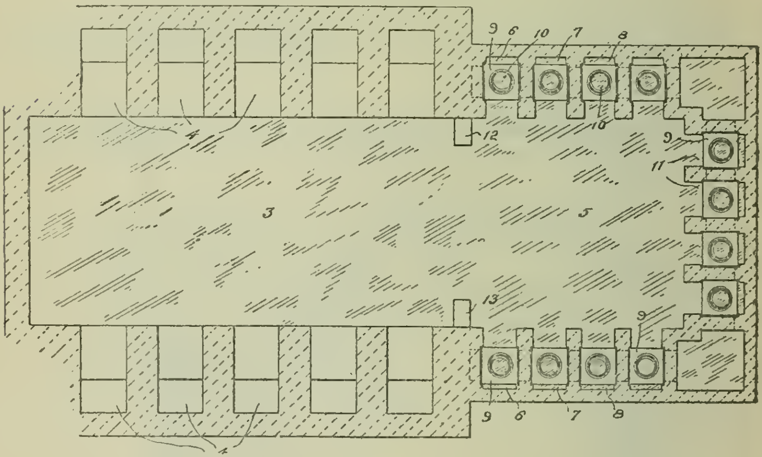


Fig. 156.

270. Drawing Glass Cylinders. Levi Sherman (U.S.A. Pat. March 5th, 1918, No. **1258159**. Filed June 9th, 1917, No. 173799).—The invention consists of a floating drawing-pot for use with a tank furnace. The pot consists of a cylindrical fireclay body, 4, having a bottom, 5, formed with an opening, 6. A circular baffle plate, 7, of greater diameter than the opening, 6, is supported a little distance below the bottom, 5, by means of lugs, 8. The baffle assists in supporting the pot, so that normally the bottom, 5, is level with the surface of the metal, as shown. In use, the drawing-shield, 3, is lowered to depress the pot so that the metal from which the cylinder is drawn enters through the opening, 6. The baffle, 7, protects the metal in the pot from radiation, and also prevents chilling of the body of metal beneath the pot. After the cylinder is drawn, the pot is pushed into the body of the tank, where the greater heat melts the aftermath, which flows out through the opening, 6. G. D.

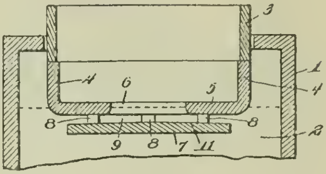


Fig. 157.

271. Drawing Glass Cylinders. G. L. Catlin and D. Morrison (U.S.A. Pat., February 12th, 1918, No. **1255983**. Filed May 19th, 1917, No. 169711).—A drawing-pot consists of a topstone, 11, having a depending flange or body, 12, and a reversible bottom, 16, mounted on trunnions, 20. The rim, 18, of the bottom which makes contact with the flange, 12, is very narrow in order to permit expansion of the rim, 17, and to minimise sticking between the topstone and the bottom. The bottom is raised and lowered by means of worm gear, 33, and the trunnions, 20, are supported by springs, 26, in order to permit expansion of the rim, 17, and yet secure good contact between the rim and the flange, 12. The pot is mounted in a furnace, 14, supplied with gas burners, 13, to melt the aftermath off the bottom, 16, after it is reversed. G. D.

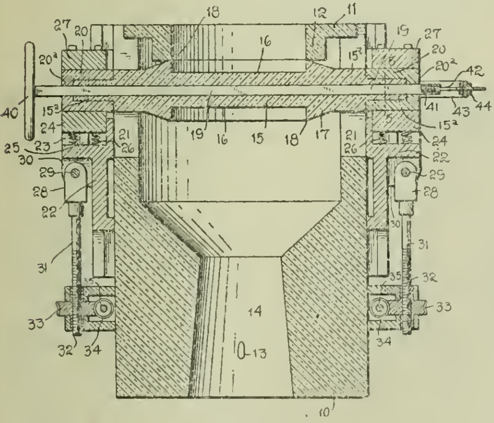


Fig. 158.

272. Drawing Glass Cylinders. L. S. Skelton (U.S.A. Pat. December 30th, 1919, No. **1326296**. Filed June 26th, 1917, No. 176973).—The invention relates to the drawing of glass cylinders,

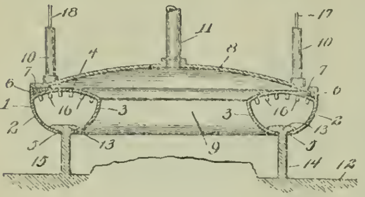


FIG. 159.

and consists of a bait designed to avoid the breaking of the neck of the cylinder and imperfect formation of cylinder necks due to faulty control of the air supply.

The bait consists of a hollow annular member having a domed top wall, 4, and curved lower walls, 2, 3, which are separated at their lower ends to form a slot, 5. This bait is screwed to a cover, 8, having an air pipe, 11, as usual. In use, the bait is lowered into the metal, 14, which passes through the slot, 5, and forms a neck, 13, that supports the cylinder, 14. The slot, 5, is of the same diameter as the cylinder, so that losses due to imperfect formation of the neck of the cylinder are avoided.

The temperature of the interior of the bait is kept constant by means of an electrical heating device, consisting of a resistance wire wound on insulators, 16, secured to the interior of the top, 4. A modified form of bait is illustrated, but is described more fully in a co-pending application. G. D.

Reviews.

Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry, Vol. IV. 1919.—The Annual Reports of the Society of Chemical Industry have now become well established and provide an exceedingly useful review of the whole field of applied chemistry, including such varied industries as Fuels, Gas and Mineral Oils, Colouring Matters, Textiles, Cellulose and Paper, Glass, Refractory Materials, Chemicals and Building Materials, the Metallurgical industries, Paints, India-rubber, etc. The particular sections which will be of interest to the readers of this JOURNAL are those on Glass, Refractory Materials, Fuel, Plant and Machinery. The section on glass extends to an eight-page review, and affords in a very small space a *résumé* of the year's activity. The section on refractory materials fills eleven pages and again there seems no important omission from its report of the year's work. The section on fuel very well deserves perusal by all who are interested in fuel economy and conservation. A considerable amount of progress has been made on this subject during 1919 and the summary is particularly useful. For those whose time is taken up too much to enable them to follow closely the progress made in the various branches of technical chemistry, there is no better method of keeping in touch with the progress of chemical industry than through these annual reports, of which the present volume is a very successful number. W. E. S. T.

I.—Glass-making Materials.

273. Drying Sand. A. P. Digger, Coventry (Brit. Pat. No. **136379**. February 17th, 1919, No. 3876).—Relates to a machine for drying sand for use in foundries or for other purposes. The dryer consists of a rotatable cylinder, *C*, the shaft, C^4, of which is journalled in bearings in the removable end covers of an inclined stationary casing, *A*. The cylinder has longitudinal ribs or baffles on its inner surface to agitate the sand, and is heated by gas burners, *D*, or by electric coils. The casing has trunnions, A^2, which rest on bearings in a standard, *B*, and is supported near its lower end by a crew, B^4, which enables the inclination, and therefore the rate of the flow of the sand through the cylinder, to be varied. The moist sand is fed from a hopper, *F*, into the cylinder through an aperture into the upper end cover of the casing, and, after being dried by contact with the heated cylinder, is discharged through an aperture in the lower end cover. H. G. C.

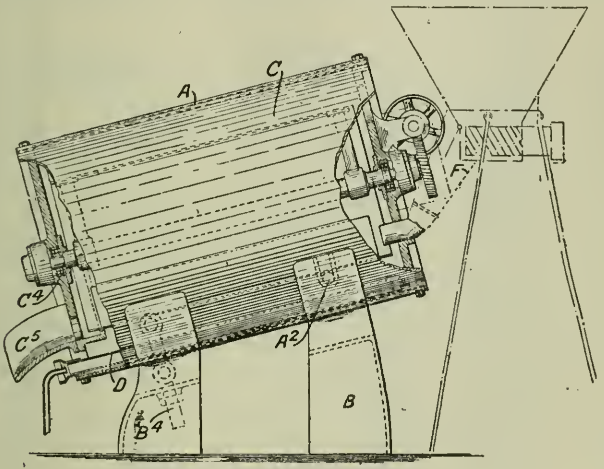


Fig. 160.

II.—Glass: Manufacture and Properties.

274. The Thermal Dilatation of Glass at High Temperatures. C. G. Peters and C. H. Cragoe (*J. Optical Soc. Amer.*, 1920, **4**, 105).—The first portion of the paper was devoted to a very complete summary of previous work All the published

TABLE I.

No.	SiO_2.	CaO.	Na_2O.	As_2O_5.	MgO.	ZnO.	PbO.	BaO.	Fe_2O_3.	Al_2O_3.	B_2O_3.	Sb_2O_3.	K_2O.
1—2	58·8	—	1·7	—	—	2·5	12·7	14·3	—	—	1·7	—	8·3
3*	71·3	12·5	13·4	0·9	0·3	—	—	—	0·1	—	—	—	0·1
4*	72·0	10·2	16·2	0·3	—	—	—	—	0·1	—	—	—	0·3
5*	71·5	12·4	13·7	0·1	—	—	—	—	0·1	—	—	—	—
6*	72·5	11·5	13·8	—	—	—	—	—	0·1	—	—	—	0·2
7*	71·3	14·7	10·4	—	—	—	—	—	0·4	—	—	—	0·4
8	67·0	—	12·0	0·4	—	1·5	—	10·6	—	—	3·5	—	5·0
9	68·6	—	12·0	0·2	—	1·0	—	9·7	—	—	3·5	0·5	5·0
10	66·5	—	9·8	0·2	—	2·0	—	7·8	—	—	7·8	—	5·9
11	47·6	—	2·0	1·4	—	9·9	—	29·2	—	—	4·0	—	6·0
12	44·3	3·0	3·5	0·2	—	—	44·0	—	—	—	—	—	5·0
13	53·9	2·0	1·0	0·3	—	—	35·2	—	—	—	—	—	7·6
14	54·0	2·0	1·0	0·3	—	—	36·7	—	—	—	—	—	6·0
15	67·0	—	12·0	0·4	—	1·5	—	10·6	—	—	3·5	—	5·0
16	74·0	5·8	17·1	—	3·1	—	—	—	—	—	—	—	—
17	74·3	5·5	17·2	—	3·0	—	—	—	—	—	—	—	—
18—19	74·0	7·2	16·1	—	2·7	—	—	—	—	—	—	—	—
20*	73·0	0·7	10·8	—	4·3	5·6	—	—	0·4	1·0	3·6	0·6	0·3
21*	80·5	0·3	4·4	0·7	0·1	—	—	—	0·3	2·0	11·8	—	0·2
22*	64·7	0·6	7·5	0·1	0·2	10·9	—	—	0·3	4·2	10·9	—	0·4
31—32*	71·9	—	11·0	—	—	—	—	—	—	5·0	12·0	—	—

* The samples marked with an asterisk were analysed. Batch compositions are given for the rest.

data relating to glasses of known composition were collected and arranged in tabular form. Most of the observations dealt only with the dilatation at temperatures below 100°, and the purpose of the present experiments was to determine the dimensional changes in the annealing temperature region. The methods employed by previous investigators were reviewed, and an interference method was chosen. A full description of the apparatus and procedure was given. Thirty-one glasses were examined, their compositions being given in Table I and their coefficients of expansion in Table II.

TABLE II.

No.	Designation.	Temp. interval °C.	$\alpha \times 10^4$.	Temp. interval °C.	$\alpha \times 10^4$.
1–2	Barium Flint, B.S. 145 ..	22—494	0·088	519—550	0·331
3	Plate, American	19—461	0·099	563—579	0·373
4	Do.	20—508	0·108	540—560	0·401
5	Do.	23—494	0·101	564—583	0·460
6	Plate, German	21—496	0·099	564—589	0·477
7	Plate, French	21—513	0·094	597—613	0·424
8	Light Crown, B.S. 103 ..	24—422	0·104	494—507	0·548
9	Light Crown, B.S. 20 ..	22—426	0·102	502—522	0·555
10	Borosilicate Crown, B.S. 94	22—498	0·090	539—562	0·393
11	Barium Crown, B.S. 87 ..	23—499	0·090	589—610	0·649
12	Medium Flint, B.S. 110 ..	23—402	0·097	452—478	0·396
13	Light Flint, B.S. 188	22—451	0·088	494—512	0·347
14	Light Flint, B.S. 33	23—420	0·076	495—511	0·292
15	Light Crown, B.S. 103 ..	24—422	0·104	496—505	0·550
16	Commercial Glass	23—445	0·107	510—534	0·309
17	Do.	22—452	0·103	—	—
18	Do.	22—464	0·102	523—552	0·318
19	Do.	21—474	0·102	544—557	0·316
20	Macbeth-Evans flask	22—449	0·069	567—586	0·454
21	Pyrex..................	21—471	0·036	552—571	0·151
22	Schott & Gen. flask......	19—414	0·056	540—562	0·404
23	Soda tubing	21—372	0·120	506—525	0·234
24	Lead tubing	21—338	0·091	464—483	0·236
25	Lead tubing	21—345	0·096	457—477	0·225
26	Fluorite tubing	22—364	0·098	510—561	0·284
27	Lead tubing	21—333	0·097	430—469	0·227
28	Vacuum tube tubing	23—405	0·116	509—545	0·205
29	Fusing in glass, German..	23—383	0·090	456—481	0·283
30	Fusing in glass, Corning..	22—376	0·083	460—485	0·258
31	Jena 59 III, pll. to axis ..	38—522	0·064	564—600	0·437
32	Jena 59 III, $\perp$ to axis ..	22—491	0·062	562—603	0·452

The expansions were also represented graphically. They were very regular during the first 350° to 550°, but, on heating further, the rate of expansion changed. With well-annealed glasses it increased rapidly; with unannealed it first decreased, then increased. The region in which the change took place was found to coincide with the annealing temperature. Above the highest temperature given in the table, a rapid decrease in the rate of expansion took place, followed by a contraction. If the rod was cooled after the contraction had commenced, it returned to its original length, provided the highest temperature did not exceed the critical or annealing temperature. If held at a constant temperature in the critical region, it first expanded and then slowly contracted. Above the critical region, the contraction increased with temperature. The dimensional change above this temperature was investigated in detail for glasses 2 and 11. It was found that the samples underwent a permanent decrease in length. This was attributed to the effect of surface tension when the glass was fluid, that is, above the critical temperature. Heat absorption occurred in the same temperature range as the critical change in expansion. J. R. C.

275. The Binary System Åkermanite–Gehlenite. J. B. Ferguson and A. F. Buddington (*Amer. J. Sci.*, 1920, **50**, 131).—The binary system *åkermanite* ($2CaO,MgO,2SiO_2$)–*gehlenite* ($2CaO,Al_2O_3,SiO_2$) formed a complete series of solid solutions with a minimum melting point at 1388°. The minimum melting point corresponded to a composition of about 74 per cent. *åkermanite* and 26 per cent. *gehlenite*, and was 70° below the melting point of *åkermanite*, the component with the lower melting point. The optical characters of crystals of certain intermediate compositions were found, on determination, to be a continuous function of the composition. The isomorphous character of the system was confirmed by the densities of crystals and glasses of *åkermanite–gehlenite* and several intermediate mixtures. *Åkermanite* glass had a higher density at 25° than the corresponding crystals.

F. W. H.

276. An Approximate Determination of the Melting-point Diagram of the System Zirconia–Silica. E. W. Washburn and E. E. Libman (*J. Amer. Cer. Soc.*, 1920, **3**, 634).—The silica employed was pure quartz powder, and the zirconia, obtained from zirconium hydroxide by ignition, contained 99·17 per cent. of ZrO_2 and 0·71 per cent. of Fe_2O_3. This iron was completely removed by heating the material in a tube furnace at 300° whilst a current of phosgene gas was passed through.

The melting temperatures investigated were those of pure zirconia and mixtures of zirconia and silica in the following molecular proportions:—ZrO_2,SiO_2, $ZrO_2,2SiO_2$, $ZrO_2,3SiO_2$, $2ZrO_2,3SiO_2$, $2ZrO_2,SiO_2$, $3ZrO_2,SiO_2$, and $3ZrO_2,2SiO_2$. An elaborate method of mixing, grinding, fusion, re-grinding, extraction with dilute hydrochloric acid, and washing was repeated three times with each mixture. Then after burning to a cherry-red heat in a stream of oxygen, the mixtures were pure white.

Portions of each mixture were made into sticks, using an electric arc, well-fused crystalline pencils about 2 inches long and one-eighth inch diameter being obtained. The melting points were determined by feeding a stick slowly into an oxy-acetylene flame and noting the temperature of the small drops of fused material on the tip of the stick by means of an optical pyrometer. The temperature readings could be duplicated to about ±100°. The following are the estimated "true" melting points of the mixtures expressed in molecular proportions:—ZrO_2, 2720°; $3ZrO_2,SiO_2$, 2685°; $2ZrO_2,SiO_2$, 2650°; $3ZrO_2,2SiO_2$, 2460°; ZrO_2,SiO_2, 2550°; $2ZrO_2,3SiO_2$, 2420°; $ZrO_2,2SiO_2$, 2420°; $ZrO_2,3SiO_2$, 2420°; natural zircon, 2550°.

The mixtures on the ZrO_2 side, composed of ZrO_2 and $ZrSiO_4$, melted quickly, were very fluid, and the drops were perfect spheres showing complete liquefaction. The mixtures on the SiO_2 side, composed of SiO_2 and $ZrSiO_4$, fused with difficulty.

The results indicated that for use as a refractory up to 2550° the presence of silica as an impurity in zirconia was not necessarily detrimental, since addition of SiO_2 up to a 33 per cent. total eliminated its fluxing action. Such a refractory would have the properties of zirconium silicate, but would be nearly as resistant to high temperatures as pure zirconia. Refractories of considerable strength, it was suggested, could possibly be made from powdered zircon bonded with a mixture of zirconium hydroxide and silica in molecular proportions and fired in an electric furnace. F. W. H.

277. Note on the Motion of the Stirrers Used in Optical Glass Manufacture. E. D. Williamson and L. H. Adams (*J. Amer. Cer. Soc.*, 1920, **3**, 671).—The authors discussed mathematically, for two simple cases, the shape of the curve traced by the stirrer in the glass, the variation in the velocity of the stirrer at different parts of the curve, and the area of the curve traced in relation to the surface area of the glass in the pot. F. W. H.

278. The Manufacture and Uses of Rolled Optical Glass. H. S. Roberts and J. C. Hostetter (*J. Amer. Cer. Soc.*, 1920, **3**, 750).—The glass, made in the usual way for optical glass, was poured from the pot, after stirring in a large circle at low speed, and subsequently treated as ordinary plate glass. There was a great saving in pots and pot-arching, and the glass might be made in the usual plate-glass furnace. Large sheets of optical glass were obtained in thicknesses up to two and a-half inches. Polishing and cutting to size were very easily accomplished, there was much less waste in the cutting, and rolled optical glass could reach the final inspection within a week of pouring.

The uses of this type of glass were obviously somewhat restricted, since some striæ were necessarily present. When working up the glass it was necessary to take into account the fact that it contained a certain amount of parallel layers of glass, differing in refractive index from the main portion. It was necessary to choose the glass for various optical systems so that the path of light rays cut the striations in a direction as nearly as possible normal to the direction of the striations themselves. This method of manufacture was eminently suitable for the large-scale production of glass suitable for photographic lenses, field glasses, spectacles, etc. For instruments of highest precision, the ordinary process of cooling the glass in the pot must be used.

The method of manufacture and inspection of the glass and the manner of forming the glass into blanks for lenses and prisms were described in detail and illustrated by diagrams. The following casting and annealing temperatures were given:—

Type of glass.	n_D	Casting temperature.	Annealing temperature.
Ordinary crown ...	1·52	1205°	570°
Barosilicate crown ...	1·515	1205°	590°
Borium crown ...	1·57	1175°	580°
	1·61	1205°	600°
Ordinary flint ...	1·575	1220°	465°
	1·616	1190°	455°
	1·65	1150°	445°
Barium flint ...	1·61	1175°	—

F. W. H.

279. A Method for Determining the Annealing Temperature of Optical Glass. J. T. Littleton and E. H. Roberts (*J. Optical Soc. Amer.*, 1920, **4**, 224).—The author assumed that the rate of annealing of a glass was proportional to its viscosity, and, having ascertained the annealing temperature of a standard glass and its viscosity at this temperature, he further assumed that the annealing temperature of any glass was the temperature at which it had this viscosity. The annealing temperature of the standard glass was determined in the usual way by observing the rate at which the strain picture, presented by the glass when viewed between crossed Nicols, disappeared. The rate of annealing was found to follow the logarithmic law, $T = 10^{0 \cdot 0289(602-t)}$, where T is the time (in seconds) for complete annealing at t°. For this glass, 550° was selected as being the annealing temperature, little strain being appreciable after fifteen minutes. A method was described for measuring the relative viscosities of glasses at various temperatures. By means of a pulley, a shearing couple was applied to one end of a rod of the glass under test, the other end being incapable of rotation, and the rate at which the pulley moved was taken as a measure of the viscosity. The glass could be heated in an electric furnace. For example, at 550°, a rate of 16 cm. per minute was obtained with the standard glass. Hence the annealing temperature of any glass was that temperature at which it also gave this rate of motion. It was shown that the logarithm of this rate was proportional to the temperature, and, by comparative measurements on the standard glass, the authors were able to obtain, in addition to the most practical annealing temperature, the minimum and the maximum safe annealing temperatures from their viscosity measurements. They found the assumptions made to be justified in practice, and to give satisfactorily the annealing temperatures of some optical glasses made at the Corning Glass Works. J. R. C.

280. Classification and Nomenclature of Optical Glass. G. W. Morey (*J. Optical Soc. Amer.*, 1920, **4**, 205).—An extract from the report of a Committee appointed by the Society to consider this subject. The system of nomenclature proposed was based on the crown-flint series of barium-free glasses. The dividing line between flints and crowns was at a ν value of 56. The crowns were divided into fluor-crowns (ν greater than 68), borosilicate crowns (ν greater than 61), and ordinary crowns (ν between 56 and 61). The flints were divided into extra light (ν from 56 to 50), light (ν from 50 to 38), medium (ν from 38 to 34), dense (ν from 34 to 31), and extra dense flints. Glasses falling outside the crown-flint series were grouped with the barium crowns and barium flints. The barium crowns had n_D higher than 1·60, and the light barium crowns had n_D between 1·60 and 1·54. There were also light (n_D less than 1·60), medium (n_D between 1·60 and 1·64), and dense barium flints. J. R. C.

281. Evolution and Absorption of Gases by Glass. D. Ulrey (*Phys. Review*, 1919, **14**, 160).—It was found that there was a large variation in the quantity of gases evolved per square cm. of surface from different samples of the same kind of glass. Annealing at atmospheric pressure always reduced the quantity of gases evolved on subsequent vacuum heat treatment. At a given temperature and pressure, glass was in equilibrium with a definite amount of water vapour. At temperatures up to the softening point, diffusion of the atmosphere through glass did not take place. J. R. C.

282. A Factory Method for Measuring the Viscosity of Pot-made Glass during the Process of Manufacture, together with some Discussion of the Value of Viscosity Data to the Manufacturer. E. W. Washburn (*J. Amer. Cer. Soc.*, 1920, **3**, 735).—The most satisfactory method for measuring the viscosity of glass over a wide range of temperature was the "stirring" method. In the laboratory apparatus described, the pot, cover, and stirring rod were of porcelain and the heating coils of platinum. The stirring cylinder was operated directly by a motor, the power consumption of which, P, where the angular velocity of the stirring cylinder was ω, could be determined. If k were the calibration constant of the pot and P_0 the power used in overcoming any mechanical and electrical friction in the driving mechanism, the viscosity, η, was given by the equation

$$\eta = \frac{k(P - P_0)}{\omega^2}.$$

The author suggested that, by the use of a wattmeter and speed indicator with the factory mechanical stirrer, the necessary data for computing the complete viscosity–temperature curve of the glass could be obtained during the ordinary stirring operation. Though the results obtained might not be very accurate, certain improvements in the design of the stirring equipment would improve the standard of accuracy very considerably.

An arrangement for measuring the temperature of the metal throughout the stirring operation was described and illustrated and the method of calibrating the whole apparatus indicated.

The fining of glass was dependent, not only on viscosity, but also upon surface tension, vapour pressure, and density. However, for given values of these last three factors it might be possible to obtain, in terms of viscosity, the maximum temperature a glass should attain for satisfactory fining.

In the case of optical glass where the stirring was largely depended on to ensure homogeneity of the metal, definite stirring procedure might be obtained from the viscosity data. The author suggested that if the viscosity–temperature curves for a few representative glasses were determined, using an established definite and successful stirring procedure, it might be possible to give complete directions for stirring in terms of viscosity in such a way as to be largely independent of batch composition, if not completely so. Where diffusion and convection were employed instead of stirring for obtaining homogeneity, the viscosity data should give information as to the required heat treatment.

The " stirring " method was not convenient at annealing temperatures, and the author proposed to deal with this range later.

F. W. H.

III.—Lamp-worked and General Scientific Apparatus.

283. A Direct Reading Overflow Volumeter. H. G. SCHURECHT (*J. Amer. Cer. Soc.*, 1920, **3**, 730).—The apparatus consisted of a glass bowl containing an overflow tube sealed through the bottom and extending into the interior. Underneath was placed a special burette graduated with reverse reading to receive and measure the overflow. This type of volumeter was not quite so accurate as the pyknometer type, but it was sufficiently so for clay testing and superior to the pyknometer type in speed of operation and simplicity of construction and manipulation.

F. W. H.

284. Glass to Metal Joints. E. C. MCKELVEY and C. S. TAYLOR (*J. Amer. Chem. Soc.*, 1920, **42**, 1364).—Two types of joint were discussed, namely, direct glass to metal and platinised glass soldered to metal by an intermediate layer of tin.

In connection with the second type, a review of the work of Röntgen, Cailletet, Koenig, Callendar, and Kraus was given, followed by a description of the method followed by the authors in the laboratory of the U.S. Bureau of Standards.

The glass was slightly roughened with fine emery cloth and then coated with a thin film of a colloidal solution of platinum in lavender oil and Burgundy pitch. The glass was carefully heated and then taken to incipient red heat to drive off the organic matter and leave the platinum uniformly deposited on the glass in a finely divided state. This was then placed in a metal tube of suitable shape which had been well tinned and fitted fairly tightly on the glass tube. It was preferable for the glass to butt against a shoulder in the metal joint. The whole device was then gently heated until the tinning melted and flowed, making a sound joint. Zinc chloride was used as flux. Pyrex tubing was found to be specially suitable for this type.

An objection to these joints was their unsuitability in cases where mercury was to be used.

Two forms of direct joint were discussed, the one being the direct fusion of glass to platinum tubing, and the other the use of Kraus flux to join glass to a metal shell of suitable shape. The flux consisted of zinc oxide, borax, and powdered soda glass in equal amounts, and was melted and drawn into rods for use as convenient.

The metal shell was found to lend itself to various types of joint, for example, one member of a union to connect with a metal pipe system, or to incorporate a small metal valve of a diaphragm, or, better, of a needle type when the presence of packing was not objectionable.

For connecting up in such systems, the use of tin, asbestos, or fibre washers was advocated.

In making the glass–metal joint, the glass tube was flared on to a ring of glass, which was then placed in the metal shell. The latter was externally heated until the ring fused on to it.

Joints of this type with Pyrex glass or porcelain tubes had not yet been successfully made.

The mechanical strength of soldered joints was as high as that of the glass apparatus itself. The bursting point under test was found to be 100—200 atmospheres, and in certain cases up to 400 atmospheres, which were far above the safety point for the glass part of the apparatus. Further, the joints when heated to 200° and air cooled showed no signs of cracking apart.

The fused joints appeared weakest. They withstood pressures of 70 and in very few cases up to 360 atmospheres, but they were harder to make and considerably more fragile than the soldered joint.

Pressure tests were not made on the platinum tube–glass joints, but they were unharmed by heating to 445° or cooling to −190°.

M. P.

285. Apparatus for Determination of Melting Points. L. M. Dennis (*J. Ind. Eng. Chem.*, 1920, **12**, 366).—A modification of the Thiele tube. The side-arm was bent downwards from the main tube at an angle of 45° to the vertical, and then taken up in a curve and sealed into the main tube, as in the Thiele type. The tube was heated at about the mid-point of the down bend of the side-arm. In the author's view, the new form facilitated both more uniform heating and more rapid rise of temperature. M. P.

286. A Modified Form of Smith Fermentation Tube. A. V. FULLER (*J. Ind. Eng. Chem.*, 1920, **12**, 595).—The tube was used in the investigation of organisms capable of causing fermentation in certain sugars. The bulb, *A*, was modified so that, instead of being symmetrical, it was trough-shaped on the underside to permit of the organism falling to the bottom of the gas tube proper, *B*. It was claimed that the speed with which results could be obtained was three times that with the Smith form. M. P.

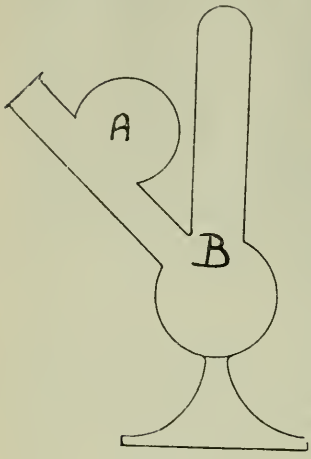


FIG. 161.

287. An Air-oven Thermo-regulator. H. M. ATKINSON (*J. Soc. Chem. Ind.*, 1920, **39**, 298).—A slightly loaded float carried at the top a small capillary, which, in conjunction with a small hole in the main body of the float, acted as a by-pass. Gas entering the float chamber from the main passed freely through the apparatus to the burner until the control bulb (two or three turns of 3/16-inch tubing) inside the oven was heated sufficiently to cause the expansion of the air to depress the mercury in one limb of the U-shaped chamber, with a consequent rise in the other limb which carries the float. The latter was thus driven

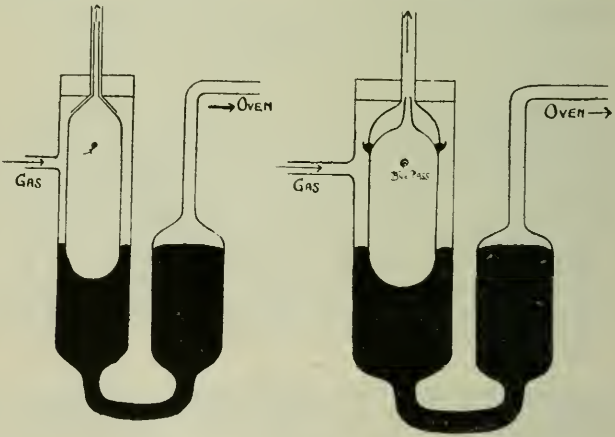


FIG. 162.

against the exit pipe from the float chamber to the burner, and, being ground to fit the latter, cut off all gas but that passing through the capillary.

An alternative form for the seal consisted, not of a ground-glass joint, but of a trough on the periphery of the float in such a position that when the float was raised it brought mercury placed in the trough into contact with the exit tube supplying the burner. The apparatus was small and compact—2·5 inches in length—and avoided troubles due to fouling of the mercury surface by the gas.

M. P.

288. An Effective Anti-splash Connecting Bulb. C. M. Clark (*J. Ind. Eng. Chem.*, 1920, **12**, 366).—The apparatus consisted of a bulb with inlet and outlet. The exit tube was sealed through the bulb, and on to the end inside the latter was sealed the baffle plate, *A*, in the form of a deep watch-glass extending to within 0·5 mm. of the side of the bulb. The vapours escaped by a small hole, *B*, blown in the side of that part of the exit tube which projected into the bulb. In a test against other forms of anti-splash still-heads, this type allowed no spray to pass over under conditions in which the others failed to hold the spray back.

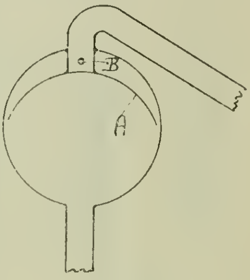


Fig. 163.

M. P.

289. A New Type of Condenser for Determination of Crude Fibre. C. A. Clemens (*J. Ind. Eng. Chem.*, 1920, **12**, 288).—The condenser consists of a glass bulb, of which one side is so blown as to extend downwards. The lower surface of this projection is concave, furnishing a ring-shaped base on which the apparatus rests when not in use. Two tubes for inlet and exit water are sealed into the top of the bulb, which is designed to fit into the top of a lipless beaker. The condenser has an increased surface

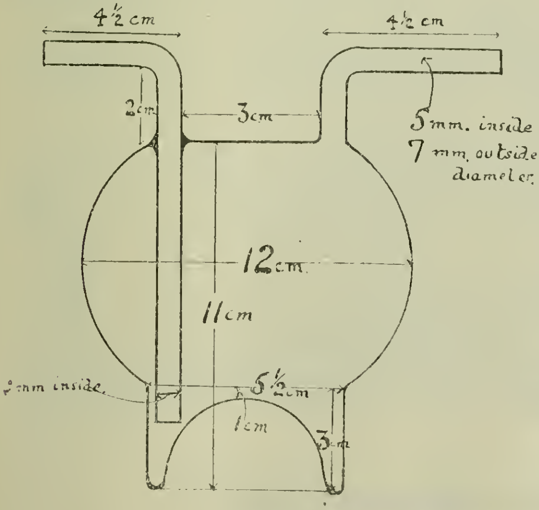


Fig. 164.

for condensation, and the construction reduces loss by evaporation to a minimum. It also effectually breaks up any foam that might otherwise froth over. The advantages claimed are wide application to various forms of lipless beaker, and ease in setting up and taking down. M. P.

290. A Thermo-regulator. J. Fitch King (*J. Amer. Chem. Soc.*, 1920, **42**, 2058).—The purest mercury used in electrically operated thermo-regulators was oxidised by the minute spark at break of circuit, thus fouling the surface. While this had been combated by displacing the air by some inert gas, the apparatus described effected a similar result by simpler means, namely, by trapping a small amount of air or inert gas by a thread of mercury, *A*, above the moving mercury column, *B*. The platinum wire, *C*, was so disposed that the spark occurred in this small space. The inert gas was introduced below the mercury surface by means of a capillary pipette, but air similarly introduced was quite satisfactory, since only a very limited amount of oxidation could take place.

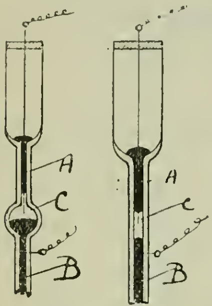


Fig. 165.

The ordinary form of thermo-regulator was suitable enough for this modification, but a more favourable type differed only by having a small bulb blown at the point where the thread of mercury trapped the small gas space. M. P.

291. A Glass Seal. L. W. Ferris (*J. Ind. Eng. Chem.*, 1920, **12**, 757).—This apparatus is for use when boiling liquids from which it is desirable to exclude the atmosphere. It consists of two bulbs blown on a tube, the lower end of which just fits the neck of the vessel to be sealed. The condensed vapour effectually completes the seal. Between the two bulbs the diameter of the tube is constricted to such a size that while the exit steam is well washed by the refluxing condensate, no mechanical loss by spattering takes place. The exit tube from the top of the upper bulb should be of a similar diameter, that is, about 7 mm. internal. M. P.

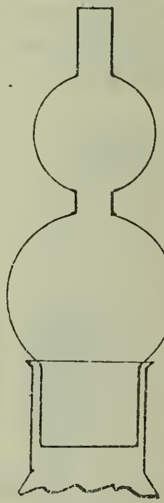


Fig. 166.

IV.—Decorated Glass.

V.—Optics and Optical Instruments.

292. Dispersion in Optical Glasses. F. E. Wright (*J. Optical Soc. Amer.*, 1920, **4**, 148, 195).—Usually the optical properties of glasses were graphically represented by plotting the mean refractive index (n_D) against the mean dispersion, $\frac{n_D - 1}{n_F - n_C}$. The author suggested that the latter quantity be replaced by the quotient $\frac{n_D - n_{A'}}{n_{G'} - n_F}$, which expressed the relative length of the red to that of the blue end of the spectrum. If partial dispersions alone were considered, it was found that if $n_F - n_D$ or $n_{G'} - n_F$ were plotted against $n_{G'} - n_{A'}$, the result in each case for a series of optical glasses was a straight line. Thus if the dispersion curve for one typical glass was known, then the whole series of dispersion curves were fixed. This law held to one unit in the fourth decimal place, and, within this limit, a change in dispersion at one part of the dispersion curve carried with it definite changes in the curve throughout the visible spectrum. Hence, if for any substance two refractive indices were given, the dispersion curve could be written down. Dispersion formulæ containing two, three, or more constants could be built up which represented the data in the visible spectrum with great accuracy, and some of them were well adapted for computing purposes.

The second paper discussed the applicability of the Cauchy, Hartmann, and Nutting dispersion formulæ to computing. The usefulness of the last-named appeared to be less satisfactory than the two-constant Cauchy formula. J. R. C.

293. The Path of a Ray through a Prism. J. P. C. Southall (*J. Optical Soc. Amer.*, 1920, **4**, 283).—Two new solutions were described, one graphical, of the problem referred to in Abs. No. 26.
J. R. C.

294. The Path of a Ray through a Symmetrical Optical Instrument. J. P. C. Southall (*J. Optical Soc. Amer.*, 1920, **4**, 294).—A paper of theoretical interest leading to an approximate method of calculating this path. J. R. C.

295. Special Cases in Lens Calculation. C. W. Woodworth (*J. Optical Soc. Amer.*, 1920, **4**, 286).—This paper deals with certain sources of error which are unavoidable in lens calculation owing to inevitable inaccuracy in the physical data. Such a case is the determination of the magnitude of the distant focus. Methods of surmounting some of the difficulties were described. J. R. C.

296. A Focal-length Equation. C. W. Woodworth (*J. Optical Soc. Amer.*, 1920, **4**, 243).—A general equation was

given for calculating the focal length of a lens system, and its application is illustrated by an example. In a note on this paper, J. P. C. Southall shows that the equation, though never previously published, is equivalent to two formulæ derived by T. Smith.
J. R. C.

297. Axial Aberrations of Lenses. E. D. Tillyer and H. I. Shultz (*Bull. Bur. Standards*, 1918—1919, **14**, 341).—The errors which affected the definition of a lens were discussed, and methods of representing graphically the central errors were described. A new method was given whereby all the important central errors could be determined by one set of measurements.
J. R. C.

298. The Photographic Absorption of Lenses. G. W. Moffitt (*J. Optical Soc. Amer.*, 1920, **4**, 83).—The axial photographic transmission coefficient of a lens system was defined as the ratio of the light flux of photographic quality in the image of a small object on the axis of the system to the light flux of photographic quality that would reach the image were there no losses in the system. Apparatus was described by which this coefficient could be measured. Preliminary results showed good agreement with visual determinations and with those theoretically obtained. J. R. C.

299. Invisible Light. R. W. Wood (*Proc. Phys. Soc.*, 1919, **31**, 232).—Reference was made to a glass coloured by nickel which only transmitted ultra-violet light. J. R. C.

300. The Cemented Telescope Objective of Barium Crown and Flint. I. C. Gardner (*J. Optical Soc. Amer.*, 1920, **4**, 274).—Data and graphical representations were given which show the possible combinations of values of the three aberrations which may be obtained by the use of barium crown (n_D between 1·57 and 1·59) and ordinary flint (n_D between 1·60 and 1·66).
J. R. C.

301. The Light Transmission of Various Substances. W. W. Coblentz, W. B. Emerson, and M. B. Long (*Bull. Bur. Standards*, 1918—1919, **14**, 653).—The transmission curves of a very large number of glasses were determined, chiefly in the infra-red region of the spectrum. The glasses were classified according to their colours. Red glasses included (1) copper ruby, both flashed and homogeneous, (2) gold ruby, and (3) selenium-red. The orange glasses were coloured by selenium and some other, unknown, substance. Under the heading "Yellow glasses," there were two uranium glasses, and Corning Noviol and Noviweld, the latter being eye-protecting glasses. The green glasses were Schott's copper oxide (431 III), two Corning green glasses, Crookes' sage-green and bluish-green, and a light yellowish-green, conspicuous for its transmission in the infra-red. Several bluish-green glasses, opaque to the infra-red, and thus heat-absorbing, were also examined. Sixteen curves were given for blue, purple, and amethyst glasses, and four for black or smoked glasses. Two of Crookes' neutral-tinted glasses were found to have a high transmission in the visible, but also fairly high in the infra-red. Amongst other glasses examined were Pyrex, Fienzal, Hallaner, Euphos, and Akopos green glasses, the last four being eye-protecting glasses from various sources.

In an appendix to the paper the authors gave the percentage transmissions of fifty-three glasses with respect to (1) gas-filled tungsten lamp; (2) quartz mercury vapour lamp; (3) magnetite arc; (4) solar radiation. They also discussed the injurious effects of radiation on the eye.

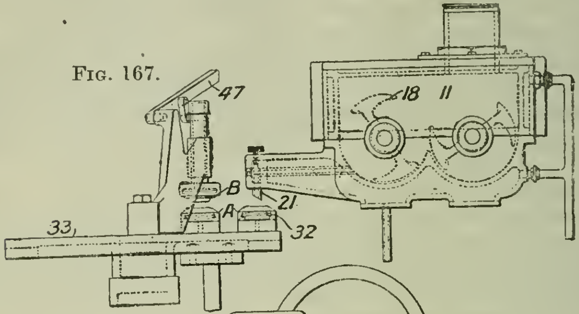
The investigations showed that in glasses which have a high absorption in the violet and ultra-violet, the effect of the colouring matter did not, as a rule, extend into the infra-red. Such glasses usually absorbed little more than colourless glass in the infra-red. Glasses which had a wide absorption band in the red and yellow usually had a marked absorption in the infra-red. J. R. C.

302. Report on Lenses and Optical Instruments. C. W. Frederick (*J. Optical Soc. Amer.*, 1920, **4**, 236).—This report was the first made by a Standards Committee, and dealt with single lens combinations only. It covered the classification of the various types of lenses, the limits of performance specifications, standards of performance, and tolerances. J. R. C.

303. Projection Screens. C. W. Gamble (*Trans. Optical Soc.*, 1919—1920, **21**, 34).—Experiments were carried out with the view of ascertaining the best screen on which to project a cinematograph picture. One screen consisted of metallic silver deposited on a thin sheet of ground glass, the natural surface of the glass facing the projector. A good image was obtained, but the brilliancy was low. Following P. G. Nutting, a glass mirror, silvered on the back and ground on the remaining surface, was also tested. Ordinary 21-oz. sheet glass was used, and this screen proved entirely successful. A similar screen was made of glass 0·25 inch thick, in order that its suitability for large screens might be tested; this was also satisfactory. Etching with hydrofluoric acid instead of grinding was also tried, but proved not to be so efficient. J. R. C.

304. Preparing Lenses, etc., for Grinding and Polishing. W. Taylor and F. W. Preston (Brit. Pat., October 14th, 1918, No. **141395**).—Relates to a method of, and means for, preparing lenses, etc., for grinding and polishing, and comprises the application of a pitch, etc., backing to the lens by means of a mould, the backing either having a central depression on the side remote from the lens, or being free from the lens at the centre, a number of lenses so prepared being then applied to a holder to form a block for grinding. The pitch is heated and mechanically stirred in a closed steam-jacketed vessel, 11, the heat being so regulated that deterioration of the pitch or loss of volatile constituents is avoided, and the stirring is accomplished by means of rotary paddles, 18; the pitch is delivered by a steam-jacketed nozzle, 21, to a mould, *A*, comprising a base, 23, supporting the lens, 32, on a rim, 24, and having a cap, 26. A number of moulds are

FIG. 167.



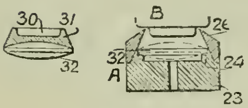


FIG. 168.

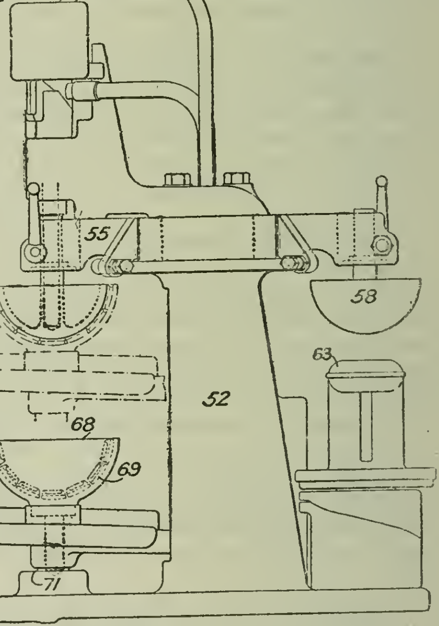


FIG. 169.

mounted on an intermittently rotated table, 33, and are positioned first under a nozzle, which sprays the lens with material to make the pitch adhere thereto, then under the pitch delivery nozzle, and finally under a plunger, *B*, adapted to be depressed by means of a lever, 47, which produces a recess, 30 (Fig. 168), in the backing, 31, surplus pitch being squeezed out between the cap and the plunger. The lenses are then placed with their unbacked face against a tool, 68 (Fig. 169), the surface of which, 69, conforms to that of the unground lenses, mounted on a ram, 71, adapted to be raised by elastic fluid to bring the pitch backings into contact with the heated surface of a holder, 58, supported on one of a pair of arms, 55, rotatably mounted on a turret on the base, 52; the other arm carries another holder, 58, which may be heated by a gas burner, 63, whilst the operation of attaching the lenses to the first holder is taking place. The holder in contact with the backings is then cooled by water, the lens backings adhering to the holder. Stops and witness-marks may be provided to indicate when the tool and holder have reached their correct relative positions. In place of forming a recess in the pitch backing, a disk of paper, or material soluble in water, may be placed over the centre of the lens surface before the pitch is introduced into the mould. The foregoing method and apparatus may be employed with backings of material other than pitch, for example, plaster of Paris or other cements. According to the Provisional Specification, the process may be used for forming lens polishers of pitch, wax, etc., attached to a metal, etc., holder. H. G. C.

VI.—Illumination and Illuminating Ware.

305. The Effect of Temperature on the Infra-red Transmission of Various Glasses. G. ROSENGARTEN (*Phys. Review*, 1920, **16**, 173).—A continuation of Coblentz's work on infra-red transmission. The experimental errors were large, but the results seemed to show that to within ±8 per cent. there was no change in the transmission of the infra-red through the glasses observed for the region 1 μ to 5 μ. J. R. C.

VII.—Fuels, Refractories, and Furnaces.

306. The Causes of Coal Waste (BRITISH CLAYWORKER, 1920–21, **29**, 62).—The causes were summarised as:—areas of firegrates and outlets at the rear of the boiler furnaces, and kiln flues out of proportion to the area and height of the chimney; fires too thin; stoking at the wrong time; stoking too heavily; fires given too much or too little air; dampers not air-tight; coal left in the ashes; fires too low before cleaning; drag used too much; lack of draught gauges to enable a battery of boilers or kilns each to secure the same draught; boilers badly seated or covered; side to bottom flues too small; uncovered boilers or steam pipes; damp and dirty coal; wet foundations and faulty design. F. W. H.

307. Pulverised Coal as Fuel. (British Clayworker, 1919–20, **28**, 200).—The use of pulverised coal for boiler firing was fully discussed, and its efficiency compared with that of boilers equipped with mechanical stokers. The author states that in flexibility, pulverised fuel approached oil or natural gas; practically every grade of coal could be used in this form; the ash was in much better condition to handle; no grates were used, and hence there was no clinkering of grates; considerably less excess air was necessary for complete combustion; all the combustible in the coal was consumed, and there was practically no smoke. Pulverised coal was fired dry, containing less than 1 per cent. of moisture, and the lack of moisture resulted in decreased erosion due to sulphur where high sulphur coals were used. Costs were probably less on boilers using pulverised fuel than on those stoker-fired, and the efficiency was greater. F. W. H.

308. Pulverised Fuel. Its Uses and Possibilities. (British Clayworker, 1920—1921, **29**, 72).—A review of a pamphlet issued by the Canadian Commission of Conservation giving the history of the development of pulverised coal as a fuel. In the United States it was estimated that 10,000,000 tons of coal were pulverised annually for use in the cement industry alone. All firms quoted considered the use of pulverised fuel most economical and satisfactory. F. W. H.

309. The Control of Fuel Consumption (British Clayworker, 1919—1920, **28**, 239).—Laboratory tests of heat value, coke value, percentage of ash, and moisture content of coal were regarded as essential. The percentage of clinker was greater than the percentage of ash, owing to some unburnt fuel being included. As the percentage of ash increased the thermal efficiency decreased, and with 35 to 40 per cent. of ash, the heat value of the coal became nil. High water and sulphur contents were also serious disadvantages. When buying coal, a detailed specification should be employed showing the approximate analytical results expected. The price should be fixed on the number of B.T.U.'s per penny. F. W. H.

310. Coal and the Gases Resulting from its Distillation. L. Vignon (*Ann. Chim.*, 1920, **13**, 284).—Unsaturated hydrocarbons were usually given off at temperatures below 600°. Methane and other saturated hydrocarbons were evolved in considerable quantity up to 800°, but then the proportion decreased rapidly with rise of temperature. Up to 600°, hydrogen was present in only small amounts, and was highest in proportion between 1000° and 1200°. Carbon monoxide was evolved in quantity above 1000°. The relative proportions of carbon monoxide and carbon dioxide given out varied with the distillation conditions, but the higher the oxygen content of the coal the greater was the volume of these gases obtained. F. W. H.

311. Diatomaceous (Infusorial) Earth. W. C. Phalen (*British Clayworker*, 1920—1921, **29**, 148).—Known as *kieselguhr* and erroneously as "tripoli," this substance was a hydrous silica or opal containing varying quantities of impurities. The following analyses of various samples of *kieselguhr* were given:—

	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2) ……	80·53	80·66	81·53	75·68	65·62	86·92	72·50	86·89
Alumina (Al_2O_3)	5·89	3·84	3·43	9·88	—	4·27	11·71	2·32
Iron Oxide (Fe_2O_3)	1·03	—	3·34	2·92	—	—	2·35	1·28
Lime (CaO) ……	0·35	0·58	2·61	0·29	—	1·60	0·32	0·43
Magnesia (MgO)	—	—	—	0·69	—	Trace	0·83	Trace
Potash (K_2O) …	—	—	1·16	0·02	—	2·48	1·88	3·58
Soda (Na_2O) ……	—	—	1·43	0·08	—	—	—	—
Water (H_2O) ……	12·03*	14·01*	6·04*	—	11·00	5·13	9·54	4·89
Nitrogenous matter and moisture ……	—	—	—	9·21	—	—	—	—
Total ……	99·83	99·09	99·54	98·77	—	100·40	99·13	99·39

* Water and organic matter.

It was a most effective non-conductor of heat, and hence was used, alone or with other substances, for covering boilers, steam pipes, furnaces and stoves, and in fireproof cements.

F. W. H.

312. The Commercial Application of Electrical Osmosis. J. S. Highfield, W. R. Ormandy, and D. Northall-Laurie (*J. Roy. Soc. Arts*, 1920, **68**, 514).—Particular reference was made to the application of the principles of electrical osmosis to the purification of clays and similar materials. The addition of traces of alkali to a clay suspension produced a high mobility, the clay particles remained in suspension a long time, whilst particles of pyrites, mica, felspar, free silica, and other impurities tended to settle through the suspension. The clay could then be flocculated by the addition of acid to the suspension. The disadvantages of this method of coagulation were that certain fine impurities remaining in suspension were carried down by the clay, only partial purification was obtained, the physical state of the clay was entirely altered, and it was left in a form difficult to collect and dry.

If, however, two electrodes were immersed in the suspension, the clay particles moved towards the anode and adhered to it as a coagulated mass, whilst the water was driven towards the cathode, leaving the clay in a semi-dry state. The fine particles of impurities either moved to the cathode or were washed away by the water stream moving towards the cathode. The electrical osmosis method of purification therefore removed the more finely divided impurities. Sintering occurred with osmosed clays at lower temperatures than with raw clays, thus saving fuel. The lower sintering temperature and higher melting point resulted in articles showing little further contraction after burning. The reduction of the sintering temperature was stated to be as much as 300° for low-grade clays, whilst bricks from some clays after osmosis were better burnt at 1100° than from the raw clays at 1300°.

A description was given of the apparatus for the commercial purification of clay. A machine with an anode in the form of a cylinder 2 feet in diameter and 5 feet long was said to produce about 1000 tons of pure clay per annum. The clay left the machine in the form of a blanket from one quarter of an inch to one-half of an inch in thickness containing only 25 per cent. of water, and in a form which readily admitted of drying. The cost of working varied with the class of clay. The current used varied from 20 to 70 units per ton of machine product.

A number of photomicrographs were reproduced. F. W. H.

313. The Art of Pot Making. C. O. Grafton (*J. Amer. Cer. Soc.*, 1920, **3**, 652).—The author had not discovered a single American clay which was a perfect substitute for the German clay used in pre-war days, but a blend of three American clays provided a substitute superior in many ways. After mixing the clay with clean pot shell from which all glass and vitrified material had been removed, it was transferred to a pug mill, and afterwards taken to ageing pits and left for twelve weeks. The ageing pits were covered with canvas, over which were placed heavy sacks, and the sacks were kept damp throughout the twelve weeks. No material advantage was gained by ageing the clay more than twelve weeks. When removed from the pits, the clay was again pugged, and finally tramped with the feet.

The bottom of the pot was made in four layers, 1·25 inches thick, each succeeding layer being laid at right angles to the previous layer. Rolls of clay 12 inches by 3 inches diameter were wedged out on the board to the proper thickness for each layer, about thirty such rolls being needed for each layer, and the total thickness of the pot bottom when dry was 4·5 inches. The bottom was then turned over so that it had the bevel side uppermost, and a "filling-in" spell put on, 12 inches in height, and consisting of seven hand courses and five finger courses. In putting on the hand courses, they were arranged alternately on the inside and the outside, the pot beaten up, the working being wedge-shaped. The working of the finger courses was an upward motion, the reverse of the downward worked hand courses, but alternated inside and out as the hand courses. After standing for several days to allow the clay to stiffen sufficiently to hold the next working, four 6-inch workings were put on with hand and finger courses, the same drying period being allowed between each working. The shoulder was then worked and allowed to stand for a week. For the crown the author used a little stiffer clay than that used for the pot sides, and finished the crown in one working by building the pot up a foot higher than required, and then using a glass beater to bring it down to the proper shape. Considerable skill was required to beat down the crown without caving in the entire pot. The hood was next put on and the mouth cut out, and then the inside of the crown was trimmed off to the proper thickness and smoothed, a boy of small stature being put inside through the mouth of the pot to assist in the process.

After standing on the board several weeks, the pot was thrown off and allowed to rest on the hood and front part of the bottom in order to dry the bottom. Final drying took place in a warm room.

A pot made from German clay had become thinned to less than 2 inches after seven melts of flint glass and forty-three melts of opal, and could not be taken whole from the furnace. A pot made from American clay, operated under similar conditions, gave ninety-nine fillings of opal glass.

The paper was illustrated by photographs of the process.

F. W. H.

314. Refractories. P. S. Devereux (*Chem. News*, 1920, **120**, 235).—In the author's view, resistance to high temperature was largely a problem in physical chemistry, involving the application of the phase rule and the laws of solution. Various formulæ given in text-books for calculating the softening point of a mixture from its components appeared to have been formulated without any due attention to physico-chemical laws. F. W. H.

315. Refractory Recuperator Bricks. C. Musgrove, Horsforth, near Leeds (Brit. Pat. No. **136727**. March 5th, 1919, No. 5419).—Refractory tubular recuperator bricks have squared ends forming walls, the walls being jointed by flutes or grooves, *C*, spigots and recesses forming the sealing joints for the tubular portions. H. G. C.

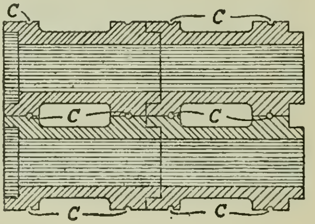


Fig. 170.

316. The Finishing Temperature of Refractory Bricks (British Clayworker, 1920—1921, **29**, 16).—A silica brick in which the quartz had been completely converted into tridymite by very prolonged heating at 1400° would expand much less than a brick fired at 1600°, but in which the whole of the quartz had not been so converted. During tests by H. M. Howe, of the Mellon Institute, Pittsburgh, U.S.A., bricks of reputed high quality were heated under a pressure of 25 lb. per square inch from 1100° to 1450°, and the change in volume measured for every 50° increase of temperature. Up to 1200° no change occurred, but there was a slight contraction between 1250° and 1400°, and a slight expansion at 1450°. This showed that firing these bricks at 1250° was sufficient, even if they were to be used at 1500°, and it was not necessary, therefore, in every case to fire bricks at a temperature as high as that to which they would be exposed in use. The shrinkage or expansion in use depended less on the temperature of firing than on the duration of the firing. F. W. H.

317. The Ultramicroscopic Examination of some Clays. J. Alexander (*J. Amer. Cer. Soc.*, 1920, **3**, 612).—The properties of clays were influenced by chemical constitution and the degree of subdivision or aggregation of the clay particles.

Experiments were carried out by the author with the view of collating the properties of a clay with the size of its particles and the activity of motion of the colloidal matter. The observations were tabulated, the clay particles being classified as large (about 0·025 mm. diameter), small (about 0·005 mm. diameter), or colloidal. Reticulated particles were large particles formed of smaller individuals united by coagulation, dehydration, heat, pressure, or some combination of these factors. Colloidal motion, crystalloidisis, order of acidity with litmus, ease of mixing with water, feel, and appearance were other points noted.

The author observed that the comparative freedom of the English kaolin from large particles demonstrated the care with which the washing and flotation had been accomplished. The activity of the colloidal motion indicated absence of coagulating agents, and perhaps addition of deflocculators, either intentionally or in the local water used. The tensile strength of the dry clay was about 30 lb. per square inch, compressive strength about 200 lb., and transverse strength about 70 lb. per square inch. It appeared that the relative weakness of the dry clay was due to the uniformity of its particles, and also their hydration.

F. W. H.

318. Recuperative Glass Furnace. J. S. Atkinson, Messrs. Stein and Atkinson, and T. C. Moorshead (Brit. Pat., October 11th, 1919, No. **141617**).—In a glass furnace of the kind in which a rotating table, 2, and trough, 3 (or pots), for the most part within the furnace, carry the glass to a gathering or removal point just without the furnace, a gas and/or air recuperator, 7, is employed in which the waste products flow horizontally to the outlet chamber, 21, and the air or gas to be heated flows vertically

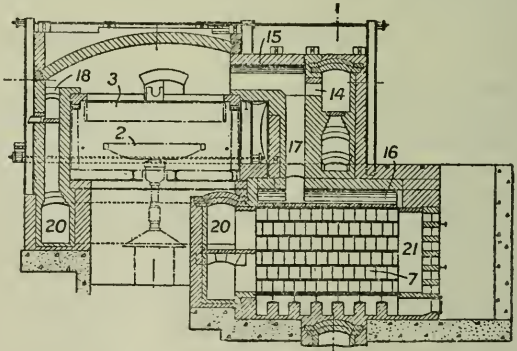


Fig. 171

without change of direction. As shown, air flows upwards through the recuperator to the chamber, 16, and thence by flues, 17, to the passages, 15, where it meets gas from the ports, 14. The flames, etc., flow direct to the outlets, 18, which are either in the opposite or the adjacent wall, and thence by flue, 20, to the recuperator.

H. G. C.

319. Regenerative Furnaces. S. G. Curd (Queenborough, Kent (Brit. Pat. No. **135636**. May 5th, 1919, No. 20306/18). —In a regenerative glass-melting furnace fired with producer gas, the producer gas is passed over a mixture of iron and carbon before entering the furnace to enrich and improve the heating qualities of the gas, and it is further enriched by mixing it with gaseous products, such as hydrogen and carbon monoxide, obtained by passing superheated steam over a similar mixture of iron and carbon. Figs. 172 and 174 show transverse and longitudinal sections of a glass-melting furnace with the invention applied thereto. The furnace comprises a melting tank, 1, separated by a perforated partition, *H*, and wall, 6, from a reservoir, 2. Holes, *G*, permit glass to flow from the tank to the reservoir. Gas and air ports controlled by valves are arranged on each side of the melting tank, the air ports being in communication with reversible air regenerators, C^1, and being provided with inspection openings, 7. Air channels, *N*, below the melting tank and vertical channels between the vertical gas and air passages at the sides of the furnace are provided for cooling the hearth and side walls. The lower part of each air regenerator, C^1, is provided with a steam superheater, *T*, which supplies steam through the pipe, *K*, to the chamber beneath a grate, 10, supporting a mixture of iron and carbon. When gas and air are being supplied through the left-hand ports of the melting tank shown in Fig. 172, air passes to the furnace through the regenerator, C^1, and ports, R^1, and waste gases escape through the opposite regenerator. Gas enters beneath the grate, 10, and passes up through the mixture of iron and carbon to a gas chamber, *C*, communicating with the ports, *R*. The waste gases passing through the opposite regenerator, C^1, superheat the steam in the superheater, *T*, and the steam passes up through the

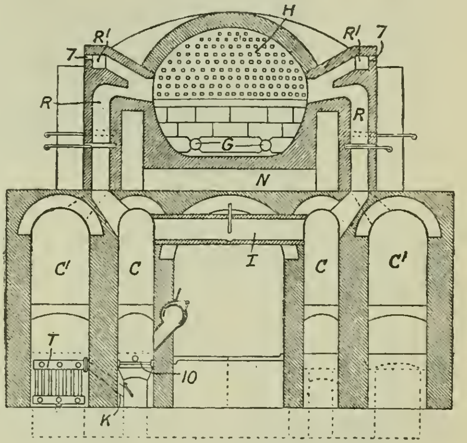


Fig. 172.

mixture of iron and carbon and is dissociated, hydrogen and carbon monoxide being produced in the chamber, *C*, and passing through valve-controlled pipes, *I*, to the opposite chamber, *C*, and to the furnace with the producer gas. A modified form of glass-melting tank having a central partition, H^1, with or without perforations, is shown in Fig. 173. H. G. C.

FIG. 173.

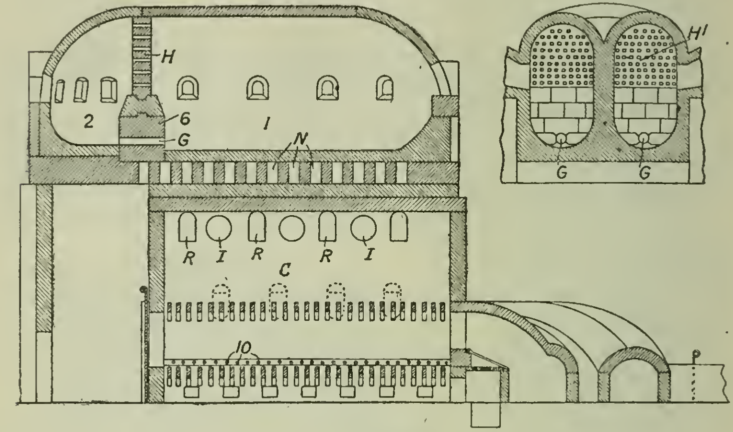


FIG. 174.

320. Gas-fired Furnaces. J. R. C. AUGUST (Brit. Pat. February 12th, 1919, No. **139276**).—In a gas-fired furnace for hardening or tempering steel tools, or for heating or annealing metals, glass, pottery, etc., regeneratively heated gas and air are supplied through pipes, 3, 4, respectively, to a combustion chamber, 5, having inclined sides, and floor, 7, inclined upwards towards the outlet leading into the preheating chamber, 1, which is in communication with the hardening chamber, 2. The roof of the combustion chamber is rounded, and serves to deflect the gas downwards. The combustion products from the furnace escape into a hood, 8, which encloses the air regenerator tubes, 11, cast integrally with headers and with the hood. The gas is heated in pipes arranged as shown above the air conduits. A similar combustion chamber, 5, is arranged on the opposite side of the chamber, 1. H. G. C.

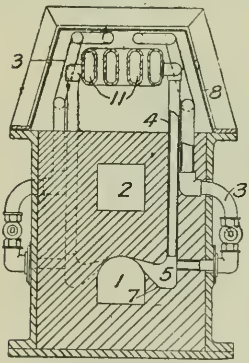


FIG. 175.

321. Gas-fired Tank Furnace. SOC. C. BOUCHER ET FILS, France (Brit. Pat., February 12th, 1920, No. **138933**).—In a gas-fired tank furnace for melting glass, the furnace proper and the gas producer are built respectively above and below the ground-level, and the air supply for combustion is heated in passages beneath the tank, in the double roof, and in proximity to the producer and its associated flue. In the construction shown, gas and air are supplied through ports in or near one end wall of the furnace, while the combustion products are exhausted at the opposite end through flues, *D*, to an underground main flue. Air-heating passages, C^1, C^2, are arranged beneath the hearth and adjacent to the main flue, respectively, and communicate with a roof flue, from which the heated air is delivered through ports, *C*, *c*, opening through the roof and the end wall of the furnace. A further supply of air from the ash-pit of the producer is heated in the flue, *B*, and delivered through openings on both sides of the gas ports, *A*. H. G. C.

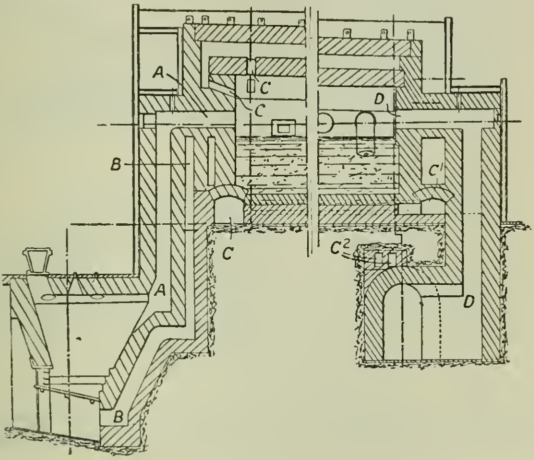
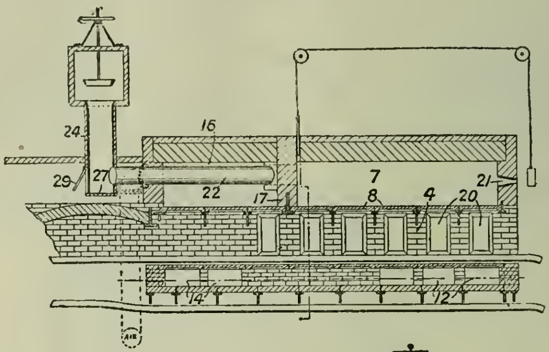


FIG. 176.

322. Gas-fired Annealing Lehr. H. M. THOMPSON, Washington, Pa., U.S.A. (Brit. Pat., March 26th, 1920, No. **140817**).—A gas-fired annealing lehr, comprising a muffle chamber, 4, with a flat floor and roof formed of tiles, 8, is heated by a combustion chamber, 7, above the roof at the forward end, and a series of flues leading to a regenerator chamber containing the gas and air supply pipes. The gas is supplied through a downtake, 24, having at its lower end a dust pocket, 27, and cleaning door, 29, and a pipe, 22, into which opens the air-supply pipe, 23, at a point near the partition wall, 17, between the combustion and regenerator chambers. The heating gases from the chamber, 7, pass downwards through side flues, 11, to transverse flues, 12, beneath the floor, leading to longitudinal flues, 13, and thence through a second set of transverse flues, 14, and side uptakes to the regenerator chamber and the stack flue. The side walls of the muffle chamber may have inset tubes, 20. Burner ports, 21, are provided in the front wall of the combustion chamber, 7, for use when oil, clean producer gas, or natural gas is used as fuel.

FIG. 177.



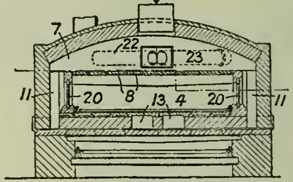
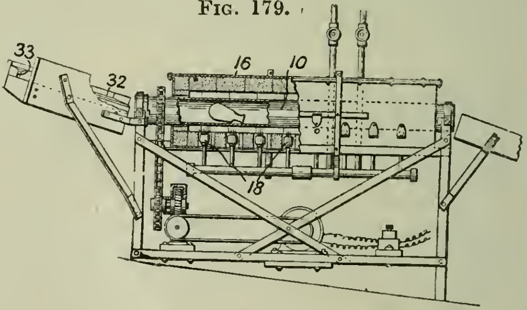


FIG. 178.

H. G. C.

323. Rotary Tube Lehr. CORNING GLASS WORKS, Corning New York, U.S.A. (Brit. Pat., January 17th, 1920, No. **140374**). —In the heat treatment of articles, for example, electric lamp

FIG. 179.



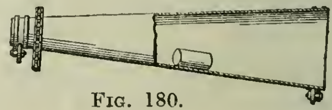
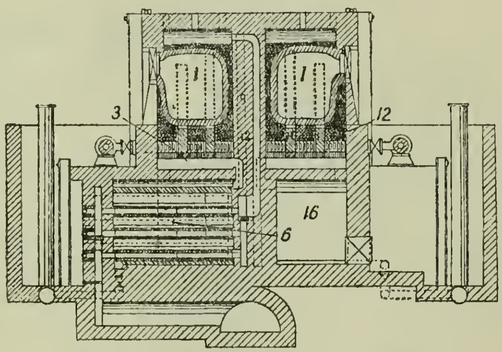


FIG. 180.

bulbs, the furnace or lehr is in the form of a rotary-heated tube, along which the articles move either by reason of the conoidal shape of the articles or the conoidal shape of the tube. As shown in Fig. 179, the rotary tube, 10, enclosed within a refractory lined chamber, 16, and heated by burners, 18, is inclined to the horizontal, and the bulbs are fed in at the lower end, smaller end first, and move up the tube, while broken pieces, not being of the correct shape, can only slide down the tube and drop out at the lower end. The feed-trough has a central guide channel, 32, and a slot, 33, for the escape of broken pieces, and, as seen in plan, is preferably inclined to the axis of the tube. Fig. 182 shows a modification in which the articles are cylindrical and the tube conoidal. H. G. C.

324. Crucible Furnace. E. C. R. Marks, London (Fours et Procédés Mathy., 2, Rue des Dominicains, Liège, Belgium) (Brit. Pat. No. **135115**. April 14th, 1919, No. 9496). — A crucible glass furnace or oven is constructed with a number of separate chambers arranged in rows, each chamber containing a crucible, 1, surrounded with fragments of porous refractory material, and being formed at its base with cavities, 12, likewise filled with such fragments, to which gas and air are supplied for flameless combustion. Beneath each chamber is a regenerator, 6, for the air. Gas is supplied through ducts, 4 (Fig. 182). Molten glass escaping from a broken crucible flows down into the air passage, 3, and thence into a chamber, 16, at the side of the regenerator through a passage which is normally closed by a thin plate of fusible alloy. H. G. C.

Fig. 181.



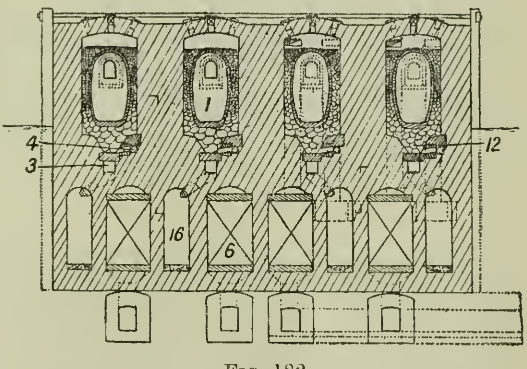


Fig. 182.

325. Report on Pyrometry. W. E. Forsythe (*J. Optical Soc. Amer.*, 1920, **4**, 305).—This first report of a Standards Committee was made in the form of a summary of existing methods and data. The data were: (1) The temperature scale and fixed points, including methods for establishing and maintaining the high temperature scale, and methods recommended for calibrating and intercomparing technical pyrometers. (2) The brightness of a black body at various temperatures and related data. (3) Spectral energies of the black body at various temperatures. (4) The constants of the black-body laws. (5) The emissive powers of various metals. Optical pyrometers were chiefly considered, and a large section of the report was devoted to the precautions necessary when using these instruments. J. R. C.

VIII.—Chemical Analysis.

326. A Comparison of Ten Different Methods of Estimation of Calcium. G. E. Ewe (*Chem. News*, 1920, **121**, 53).—The standard material used was a practically white, doubly refractive calcite. Careful preliminary determinations of the impurities led to the conclusion that the sample contained 99·959 per cent. of calcium carbonate.

The methods compared and the results obtained were as follows:—

No.	Method.	Average results.
1	Precipitation as oxalate and weighing as carbide	99·57
2	Precipitation and weighing as carbonate	100·07
3	Liberation of CO_2 by HCl and absorption in KOH	100·03
4	Precipitation as oxalate and weighing as oxide	99·86
5	Precipitation and weighing as sulphate	99·68
6	Precipitation as oxalate and weighing as sulphate	100·39
7	Precipitation as oxalate and titration with permanganate	99·68
8	Precipitation as oxalate from slightly acid solution	99·87
9	Liberation of CO_2 by HCl and calculation of CO_2 loss to $CaCO_3$	99·80
10	Residual titration	99·75

F. W. H.

327. Electro-analytical Separation of Nickel and Cobalt from Arsenic. W. H. Furman (*J. Amer. Chem. Soc.*, 1920, **42**, 1769).—In the deposition of cobalt from solutions containing arsenic or of nickel from solutions containing a fair amount of cobalt and some arsenic, the metal was always contaminated with arsenic. A quantitative separation was, however, possible if the cobalt was only present in small amount.

Actually, with static electrodes and a solution volume of 100—125 c.c. containing 29 grams of ammonium sulphate and 15 c.c. of concentrated ammonia, a current of 0·4—0·6 ampere per square decimetre at a voltage of 3·3—4·2 gave a complete deposition of nickel in from ten to twelve hours. With rotating electrodes the conditions were, for similar solutions:—current density, 1·25—3·75 amp./100 cm.^{2}; voltage, 3·6—8·6; time, 75—25 minutes; revolutions per minute, 600—800. M. P.

328. The Determination of Lead in Acid Solution. N. Evers (*Pharm. Journal*, 1920, **105**, 85).—Since the colours due to the sulphide were not comparable unless the concentration of the hydrogen ions in solution were similar, the test and standard solutions should be neutralised before the addition of hydrogen sulphide. The indicator used by the author was bromophenol-blue. If iron were present, it did not interfere with the colour under such conditions. Addition of cyanide removed the influence of copper if present. Where both iron and copper were present, the author recommended that alum should be added to the test solutions, precipitated by ammonia, filtered off, and dissolved in dilute acid. Since the aluminium hydroxide contained the lead and the copper remained in the ammoniacal solution, the solution of the precipitate in dilute acid could be used for the lead determination, as previously indicated. F. W. H.

329. The Estimation of Potassium and its Separation from Sodium by means of Sodium Cobaltinitrite. P. Wenger and C. Hemen (*Ann. Chim. anal.*, 1920, **2**, 198).—The potassium was precipitated by means of sodium cobaltinitrite solution, filtered off and dissolved in hydrochloric acid, and the cobalt content determined. Since the precipitate had the composition $K_2NaCo(NO_2)_6$, the percentage of potassium could be calculated from the weight of cobalt. F. W. H.

330. The Estimation of Minute Quantities of Arsenic by Titration. H. H. Green (*J. S. African Assoc. Anal. Chem.*, 1920, **3**, 3; from *J. Chem. Soc.*, 1920, **117** and **118**, [ii], 634).—The solution containing the arsenic was treated in the usual way in a Marsh apparatus, and the evolved gases were passed through a solution of lead acetate and through three vessels containing dilute silver nitrate solution. The whole of the silver nitrate solution was then treated with sodium bicarbonate, potassium iodide added until the precipitated silver iodide dissolved, and finally titrated with $N/500$-solution of iodine (1 c.c. $=0·1$ milligram As_4O_6). The method was serviceable for estimating quantities of arsenic from 0·05 to 5 milligrams. F. W. H.

IX.—Machinery for the Working of Glass.

331. Making Narrow-necked Bottles. J. Pullon and A. E. Clegg (Brit. Pat., April 7th, 1919, No. **139654**).—Relates to machines of the "Schiller" type for making narrow-necked bottles, and particularly to means for sucking the molten metal down into the neck mould. Compressed air escapes from a nozzle, *h*, into a conical orifice, *k*, and produces a partial vacuum in a chamber, *m*, which can be placed in communication with the neck mould by a tap, *O*. A handle, *C*, is arranged to operate the tap, *O*, through a forked lever, *q*, and also the tap for the blowing air. Instead of the ejector shown, a pump may be employed to produce the vacuum. Several machines may be connected to the chamber, *m*. H. G. C.

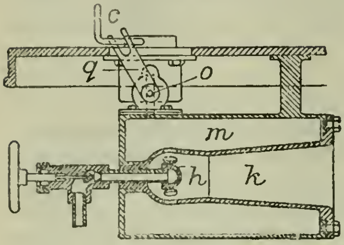


Fig. 183.

332. Machine for Making Narrow-necked Bottles.

Naamlooze Vennootschap Glasfabriek Leerdam voorheen Jeekel, Mijnssen, & Co., Leerdam, Holland (Brit. Pat. No. **136518**. March 31st, 1919, No. 8051).—In a machine for making narrow-necked bottles, the parison and finishing moulds are arranged in pairs, so that two bottles are blown at a time, the metal is forced down into the ring mould by compressed air, and the parisons are blown up against bottom moulds, or covers, to the parison moulds, which covers also serve for the introduction of the compressed air into the parison moulds. The machine, as shown in Fig. 184, has parison moulds, 3, and finishing moulds, *A*, of the usual construction, except that each mould has spaces for the formation of two articles. The parison mould is recessed for the reception of ring moulds, 10 (Fig. 185), of the scissors type, and plungers, 17, secured to a rod, 19, and operated by a treadle, 21 (Fig. 184), enter through apertures in the table, 1, to assist in the formation of the mouths of the bottles. A duplex blowhead, 25, of any suitable construction is positioned above the parison mould. It is lowered on to the parison mould by a handle, 26, and the arrangement is such that the blowing-head acts only as a mould cover until springs, 27, are compressed, when air

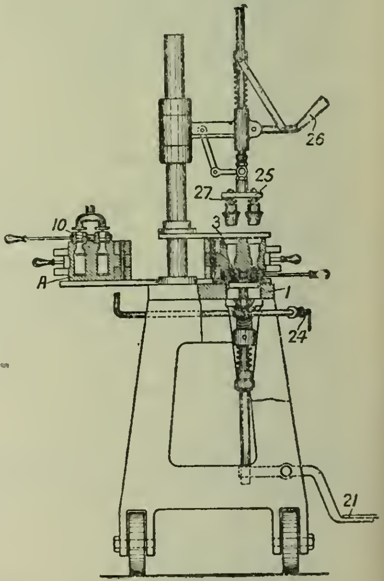


Fig. 184.

is admitted to the parison mould. In use, metal is dropped into the parison mould, and the handle, 26, drawn down to cover the moulds. Continued movement of the handle compresses the springs, 27, and admits compressed air into the moulds, so as to force the metal into the ring moulds. The handle is then raised slightly to cut off the air supply, and the parisons are then blown up against the mould covers by air admitted to the ring moulds by a valve, 24. Finally, the ring moulds and parisons are transferred by hand to the finishing moulds for the completion of the bottles.

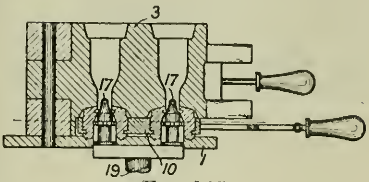


Fig. 185.

H. G. C.

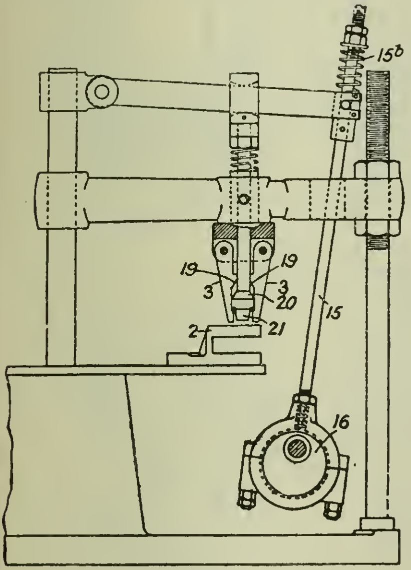


Fig. 186.

333. Mechanism for Shaping Bottle Necks. G. E. Bateson and H. A. Bateson, Liverpool (Brit. Pat. No. **134801**. August 27th, 1919, No. 20999).—Relates to a modification of the bottle neck-shaping mechanism described in Specification 8430/14. The plunger, 21, is yieldingly operated by an eccentric, 16, and spring rod, 15, 15^b. On its descent, the coned surface, 20, disengages itself from inclined surfaces, 19, on the outer formers, 3, which are then closed by a spring (not shown) on the neck of the bottle, which is held in a socket, 2.

H. G. C.

334. Automatic Glass-blowing Machine. W. J. Miller, Pa., U.S.A. (Brit. Pat., October 30th, 1918, No. **142156**).—In a machine for blowing glass articles, and of the particular kind comprising a series of blank and blowing moulds movable step by step to different stations for successive operations, means for blowing the glass in the moulds, for transferring the blank, by turning it over independently of the blank mould, to the blowing mould, and for sucking down the gather by vacuum into the blank and neck moulds, are provided. A series of blank moulds, *J* (Fig. 187), adapted to receive gatherings of glass in succession, and a series of blowing moulds, *K*, each in vertical alignment with the corresponding blank mould, are mounted on supports, *H*, *D*, which are intermittently rotated around a hollow pillar, *B*, and a suction and blowing mechanism, *M*, mounted between each blank mould and the corresponding blowing mould to rotate therewith, includes neck-forming elements, 99, and is reversible independently of the blank mould, so that the glass is subjected to suction and blowing actions in the blank mould, and then to a final blowing action in the blowing mould, from which the finished article is removed by grippers. The supports, *H*, *D*, are aligned by vertical bars, 15, to which they are adjustably connected, and screw mechanism, 7, 8, is connected by rods, 9, to the support, *H*, for adjusting this support to permit moulds of different heights to be used. A sleeve, *E*, on the pillar, *B*, is oscillated by an attached arm, in which slides a member, 33, engaging a crank-pin, 32, on a wheel rotated

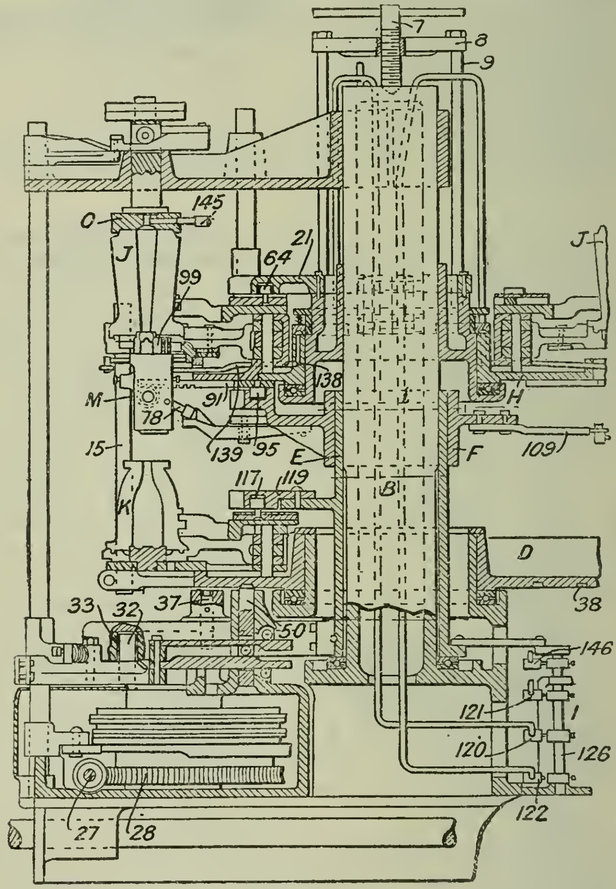
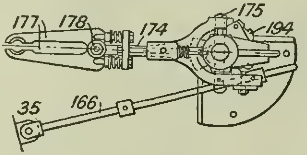


FIG. 187.

by worm gearing, 27, 28, and the sliding member, 33, has a cam groove adapted to project and retract a pin, 37, into and from engagement with recesses, 38, in the support, *D*, so that the support is moved forwards and then freed, the arm at the end of its forward movement actuating a pin, 50, to lock the support during the reverse movement of the arm. The blowing mechanism includes a cylinder, 72 (Fig. 189), containing a plunger, 76, the outer end of which is initially extended to form a depression in the neck end of the gather in the blank mould, and is subsequently retracted by an arm, 78, and a cam surface to permit the entrance of pressure fluid to the cylinder by a pipe, 139, to act on the glass. The outer end of the plunger is screwed thereto, so as to be readily changeable. The pipe, 139, is connected to a passage, 138, which is brought successively into communication with a suction chamber and three pressure chambers connected by pipes passing down to valves, 120, 121, 122, respectively, the valves being controlled by a tappet shaft, 126, oscillated by connection with the sleeve, *E*. The arrangement is such that the glass is forced down to the neck of the blank mould by pressure fluid entering a blowhead, *O*, through a pipe, 145, connected to a valve, 146, controlled by the tappet shaft, 126, is sucked into the neck mould when the suction chamber becomes operative, and has two blowings in the blank mould. This mould is then opened, and the device, *M*, is reversed to carry the partly formed article into the open blowing mould, which is then closed, and the final blowing takes place. Each blank mould comprises two sections pivoted on a vertical pin and connected by links to a yoke yieldingly connected to a slide carrying a roller, 64, engaging a cam groove in a member, 21, whereby the sections are opened and closed as the support, *H*, is rotated. The blowing mould is similarly formed and operated, but its actuating roller, 117, engages a cam groove in a member, 119, on the oscillating sleeve, *E*. The neck mould also comprises two pivoted sections, which are closed by a toggle mechanism operated by the blank mould closing means, and are opened by a cam-striker, 109, on a member, *F*, on the sleeve, *E*, to release the neck of the article after it has been positioned in the blowing mould. The blowing mechanism, *M*, is mounted on the support, *H*, and is reversed by a pinion and a rack, 91, operated through a yielding connection with a slide carrying a roller, 95, engaging a cam groove in the member *F*. The articles are taken from the opened blowing moulds by gripping members, 177 (Fig. 188), pivoted on

Fig. 188.



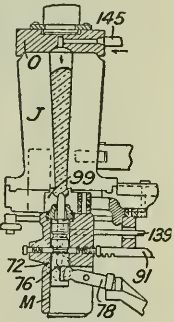
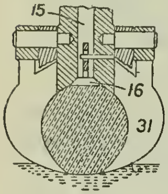


Fig. 189.

a vertical axis, 178, on an arm, 174, movable about horizontal trunnions, 175, on a rotary supporting member. The members 177 are adapted to be depressed and closed to grip an article in the opened mould, then elevated to raise the article clear of the mould bottom and swung to remove it from the mould, then lowered and opened to release the article, and finally raised and returned to their initial position, the opening and closing and raising and lowering movements being effected by cam and roller devices mounted on the arm, 174, and on a relatively movable operating member connected by a rod, 166, to the arm, 35, that oscillates the sleeve, *E*, and adjustable in height to suit the size of the mould. At the termination of each swinging movement of the arm, 174, the supporting member of the trunnions is locked by catches, 194, which are released after the parts have moved relatively to cause the cam and roller devices to operate at the start of the next movement of the rod, 166. H. G. C.

335. Automatic Gathering and Pressing Machine. W. E. Evans and M. J. Owens (U.S.A.) (Brit. Pat., August 27th, 1919, No. **142007**).—Relates to the type of automatic machine in which a number of complete units or working heads are carried by a rotating framework, and in which the metal is gathered from the tank, shaped, and the finished article discharged automatically by each unit as it rotates. According to the invention, gathering and pressing mechanism are combined in one machine. Each unit or working head comprises a suction gathering cup, 31, a mould, 45, a shearing blade, 40, and a pressing plunger, 61. When the cup, 31, arrives at the tank, 57, it is swung down into the molten metal and charged by suction, the mould, 45, being inverted, as shown in full lines, so as to pass over the tank. The cup, 31, then swings to the position shown in dotted lines, the excess of metal being cut off by the blade, 40, as the cup, 31, passes it. When the cup is clear of the tank, the mould, 45, is turned to the position shown in dotted lines, and the cup, 31, is opened to allow the metal to fall into it. The cup, 31, is opened by a rod, 23, which is connected by links, 20, with the halves of the cup, and is provided with a roller, 24, which strikes a fixed cam, 34. The plunger, 61, then descends to press the ware, which is later discharged by the inversion of the mould. The suction tube, 15, leading to the cup is fitted with a loose mushroom valve, 16, which is raised, so as to close the tube, 15, by the metal as it rises and fills the cup. The operations of the

Fig. 190.



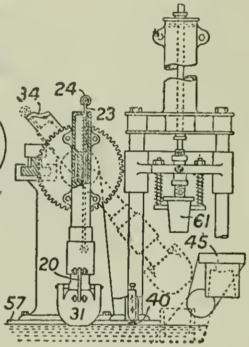


Fig. 191.

parts, including the fluid-pressure-operated plunger, 61, are controlled by fixed cams in the usual way. H. G. C.

336. Automatic Machine for Blowing Electric Lamp Bulbs. E. Lecoultré, Paris (Brit. Pat. No. **137544.** January 9th, 1920, No. 813).—Gathering molten metal; blowing; forming electric lamp bulbs. Relates to a multiple-head rotatory automatic machine for blowing electric lamp bulbs. A number of blowpipes, 42, are mounted on arms, 16, which rotate about a central shaft, 10. As each blowpipe makes one complete rotation round the machine, the following

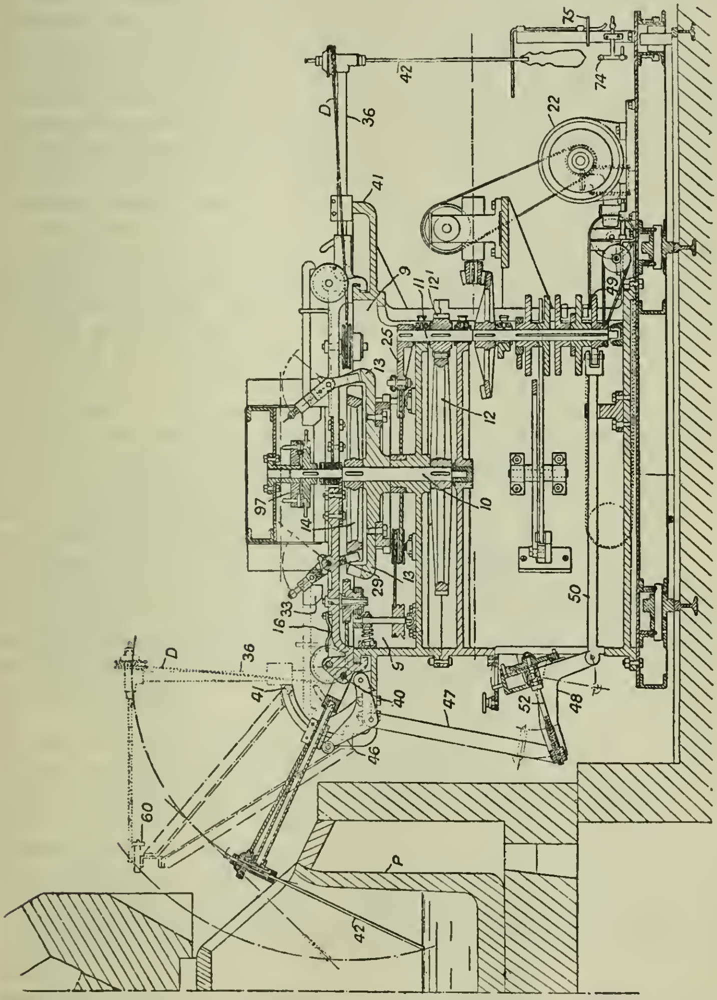


Fig. 192.

operations are performed:—(1) The blowpipe is dipped into a tank, *P*, to gather the glass. (2) It is raised and the gathering is marvered. (3) It is lowered and swung to elongate the gathering. (4) The parison so formed is blown in a mould. (5) The pip of the blown bulb is drawn out for the attachment of the evacuating tube. (6) The bulb is severed from the tube. (7) The moil is removed from the end of the blowpipe. Each blowpipe, 42, is carried by an arm, 36, pivoted at 40 to one of the arms, 16, which are loose upon the shaft, 10, and supported at their outer ends by the casing, 9. A cam shaft, 11, is driven at a constant speed by a motor, 22, and, by means of a crank, 25, and ratchet device, rotates intermittently a toothed wheel, 13, loose upon the shaft, 10, and rotates the shaft, 10, continuously by means of gearing, 12, 12^1. A detent, 29, pivoted to each arm, 16, and operated by a fixed cam, 33, engages the teeth either of the wheel, 13, or a wheel, 14, fixed to the shaft, 10, in the latter case causing the arm, 16, to swing round with the shaft, 10, and in the former case to remain at rest with the wheel, 13, or swing forward with it at increased speed. Each arm, 36, is supported and swung about the pivot, 40, by a fixed cam track, 41, which has a gap at the gathering station. At this point the arm, 36, is supported by a lever, 46, which is operated, through links, 47, 50, and a bell-crank lever, 48, from a cam, 49. The arm, 36, is lowered, as shown, for the gathering operation, and is then raised in time to continue its travel along the cam track, 41. The depth to which the blowpipe, 42, is lowered is automatically increased, as the metal in the pot is used up, by a screw, 52, which alters the effective length of one arm of the lever, 48. The gathering is marvered on a fixed plate, 60, the blowpipe, 42, being rotated by a rope drive, *D*. The blowpipe, 42, is then swung down to a vertical position and oscillated, so as to elongate the blank. The latter motion is produced by giving the cam track, 41, a sinuous form for part of its length. During a period of rest which follows the swinging operation, an ordinary two-part mould is closed round the blank, which is blown by air conveyed to the blowpipe, 42, from a central distributing device, 97, by a flexible tube.

The neck of the bulb outside the mould is cooled by an air blast during blowing. The mould is then opened, and, at the next halt, the bulb is pierced by a flame, 74, provided with an automatic re-lighting device, 75. The finished bulb is then cracked off and the moil removed from the blowpipe by cam-operated grippers. A jet of water or air may be directed upon the end of the blowpipe during this operation. Some of the operations may be controlled electrically, and suction gathering may be employed.

H. G. C.

337. Machine for Making Incandescent Lamp Stems. C. Eisler, assignor to Westinghouse Lamp Co. (U.S.A. Pat., April 27th, 1920, No. **1338500**. Filed June 6th, 1916, No. 101926).—This machine consists essentially of a pair of parallel endless belts carrying a considerable number of work-holding jaws, which are caused to advance by successive short steps between two sets of stationary burners. The clamping jaws are opened and closed by passing between two fixed cam plates, one at the end of the machine. The glass arbor and the tube with the flared end, together with the leading-in wires, are gripped in the jaws, and are not rotated as they pass through the flames, the burners on both sides being sufficient to give the necessary even heating. When the glass is sufficiently heated, the next movement of the jaws operates a cam, which causes two pressure plates to come together, and thus press the heated portions of the glass rod and tube together. This operation forms a flattened seal between the arbor and the flared tube, thus producing a firm joint, through which the sealing-in wires pass. After the release of the pressure plates, the jointed stem passes in between two burners, and then through an annealing zone, before the jaws are opened to permit of their removal. S. E.

338. Machine for Making Filament Supports for Incandescent Lamps. C. Eisler, assignor to Westinghouse Lamp Co. (U.S.A. Pat., April 27th, 1920, No. **1338499**. Filed November 12th, 1915, No. 61090).—This machine consists essentially of a drum intermittently rotated upon a horizontal axis and provided with peripheral slots, which are adapted to receive short lengths of glass rods and to carry them into contact with gas flames. When the parts of the rods passing through the flames are hot enough, the ends of the rods are subjected to pressure, thus forming the hot portions into "buttons."

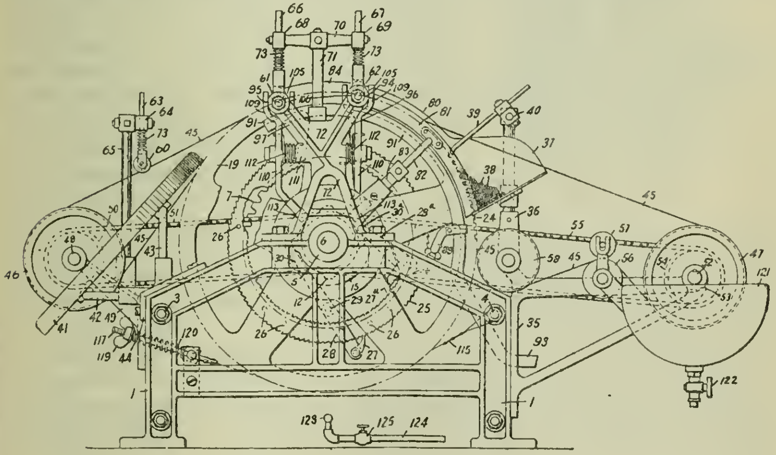


Fig. 193.

The drum is composed of a series of discs, 17, 18, and 19 (Fig. 193), the distance between the discs, 17, 19, being adjustable, thus permitting of the handling of rods of different lengths. Each of the discs is provided with a peripheral flange, which is transversely slotted at intervals, the slots in the several discs being disposed in line with each other, so that each set of slots forms a receptacle for receiving one piece of glass and carrying it through the several operations. The step-by-step movement of the drum is obtained by means of the pawl, 27, operating on the ratchet teeth on the ring, 25. This pawl is carried on one end of a lever, 28, which is pivoted at 29, and the other end of this lever is operated by the cam, 12, which carries four projections. The glass rods are fed into the slotted discs from the hopper, 37, and a set of adjustable fingers, 39, ensures that only one rod is carried forward in each set of slots. During their passage round the drum the rods are constantly rotated by means of endless steel bands, 45, one of which is provided for each of the discs. These belts are driven by passing round the driving rollers, 46, 47, and are kept taut by passing between tension rollers, 56, 57. The steel bands are passed over the top of the drum, and so arranged that the glass rods come under the bands passing in one direction and over the bands passing in the opposite direction; thus the rods are caused to rotate in their several slots so long as they are gripped between the steel bands. As soon as the rods begin to rotate, they pass over a set of flames, and then, on being carried further round the drum, one end comes up against an inclined plate, 81, which begins the compression of the rods. This compression is completed by a plunger, 94, which is operated by a lever, 110, with one end in contact with a cam disc, 15. The end button is made by suitably heating the rod, and then subjecting it to pressure by the plunger, 95.

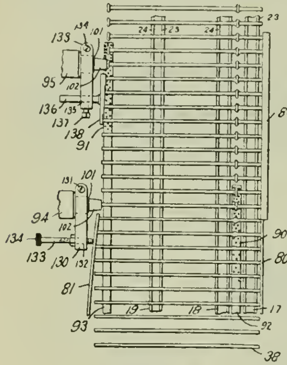


FIG. 194.

To control the movement of the drum, and especially to prevent it moving backwards, a brake, 115, in the form of a band, is provided, and acts on the lower half of the drum. Fig. 194 shows diagrammatically the progress of a number of rods through the machine. S. E.

339. Bulb-blowing Machine. O. A. HANDFORD, assignor to EMPIRE MACHINE Co. (U.S.A. Pat., January 29th, 1918, No. **1254904**. Filed November 11th, 1914, No. 871562).—The invention consists of a semi-automatic machine for blowing thin, hollow glassware, such as electric lamp bulbs, and is of that type in which the metal is gathered by hand on a blow-iron, which is then placed in the machine, the marvering and blowing being performed automatically by the machine.

As shown in sectional elevation in Fig. 196, the machine comprises a central vertical column, 1, enclosing within its base an electric motor, 3, which drives, by means of a shaft, 5, a driving drum, 9, which rotates on the column, 1. The motor also drives an air pump, 12^a, which delivers air under pressure to a storage chamber, 14, formed in the top of the column, 1. Each of the glass-working units consists of a carrier formed of a rectangular frame, 15 (Fig. 195), provided with rollers bearing on the top and bottom edges of the drum, 9, and with a clutch, 16^c, operated by an electromagnet, 25. Thus, when the clutch is disengaged, the frame, 15, is free to remain stationary while the drum, 9, revolves, but when the clutch is engaged, the frame and the carrier are forced to revolve with the drum. In the machine shown, there are three positions at which a carrier stops during one revolution around the column, 1, and it is preferable to have four carriers on the machine.

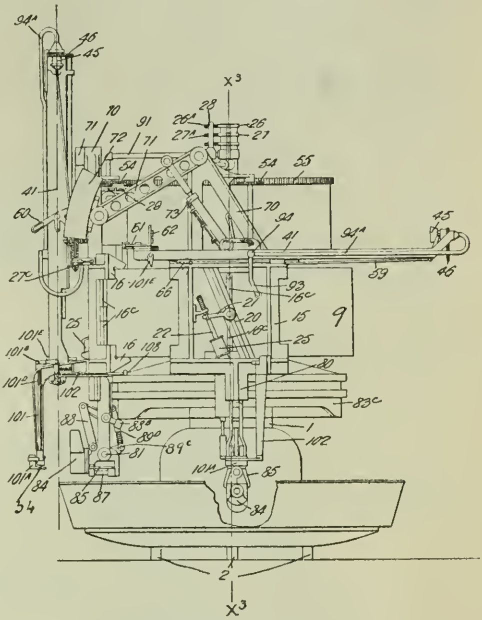


FIG. 195.

The blowpipe frame, 41, is secured to one end of a trunnion, 40, which turns in a bearing formed at the top of the carrier frame, 15. Crank arms, 42, secured to the inner end of the trunnion, 40, carry rollers, which engage in cams formed on the enlarged upper portion of the column, 1. In the starting position, the blowpipe frame is horizontal, as shown in Fig. 195, but the cams are so shaped that as the carrier moves forward, the gather end of the blow-iron is first lifted and then lowered until the frame, 41, is vertical. The frame, 41, is provided at one end with a blowpipe chuck, 45, which is rotated through gearing, 46, from a stationary gear, 55, formed on the enlarged head of the column, 1, through the medium of a bevel gear sleeved on the trunnion, 40. The chuck, 45, is movable backwards and forwards by a hand lever, 60, and also operates a pair of levers, 62, pivoted to the other end of the frame, 41, which support the lower end of the blow-iron.

The marvering device consists of an arc-shaped plate, 72 (Fig. 195), secured to an arm, 71, which is pivoted to a head, 70, rising from the upper end of the carrier frame, 15. The arm, 71, is connected to the frame, 15, by a telescopic link, 73, which is fastened on the extended position shown by a latch. When the frame, 15, commences to move, the gather is swung upwards, as previously explained, so that it is rolled along the plate, 72, and is marvered. At the top of this movement, the latch holding the link, 73, extended is tripped by the frame, 41, so that the link collapses and the plate, 72, swings down out of the way of the gather as the frame, 41, swings into the vertical position. The link, 73, is again extended when the frame, 41, moves back to the horizontal position.

The mould sections, 88, are pivoted at the lower end of a leg, 80 (Fig. 196), which extends downwards from the lower end of the carrier frame, 15. The mould normally hangs down into a water-box surrounding the base of the central column. The moulds are raised out of the water by levers, 88, 88^a, actuated by a cam, 88^c, forming the lower edge of a flange, 83^c, surrounding the central column. Another cam, formed on the face of the flange, 83^c, opens and closes the mould.

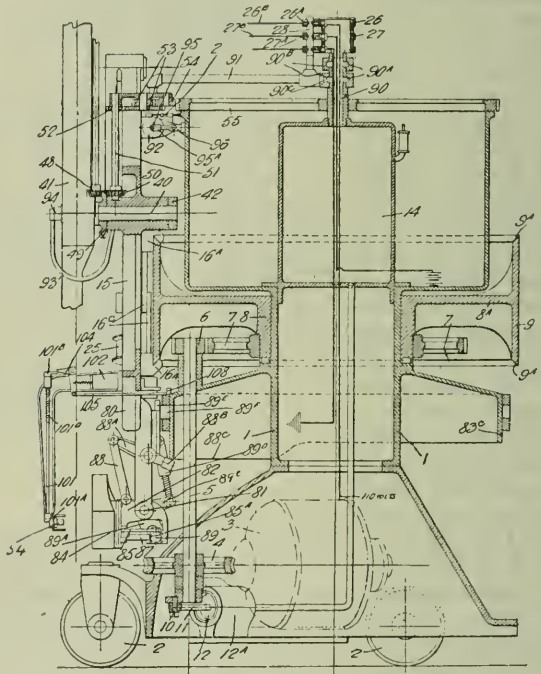


Fig. 196.

Air for blowing the gather is supplied from the storage chamber, 14, by a pipe, 91 (Fig. 196), to a valve, 92, on the carrier frame, 15, and thence by a flexible pipe, 93, to the blowpipe chuck, 45. The valve is opened at the proper intervals to admit air by cam projections on the enlarged head of the column, 1.

In commencing operations, the parts of the machine are in the position shown in Fig. 195. A blow-iron with a gather is placed in the frame, 41, and the hand lever, 60, moved to close the chuck, 45, and the levers, 62, on to the blow-iron. Movement of the hand lever closes the circuit of the electromagnet, 25, which clutches the carrier frame, 15, to the rotating drum, 9, and the carrier then commences to move around the column, 1. The frame, 41, swings the gather upwards across the marver, 72, and then moves downward to the vertical position, and at the same time the valve, 92, admits puffs of air to blow the parison. When the frame, 41, is in the vertical position, the frame is declutched from the drum, and therefore stops while the parison is elongating. Positioned adjacent to the parison is a thermostatic device, 34, which is described in U.S.A. Pat. No. **1066270**. Such a device is also described in Brit. Pat. No. **5795**/1911. This device, when the parison has elongated by the desired amount, automatically closes the circuit, so that the frame, 15, moves onwards again. The mould now closes about the parison, the blowing is completed, and the carrier stops in a reserve station close to the loading position. The blow-iron with the bulb attached can now be removed, and the frame, as soon as a new gather is inserted in the preceding carrier, automatically moves onward to the loading station. G. D.

340. Machine for Making Pressed Glassware. W. J. Miller, Swissvale, Pennsylvania, U.S.A. (Brit. Pat. No. **136816**. December 10th, 1919, No. 30955).—Relates to a machine for the

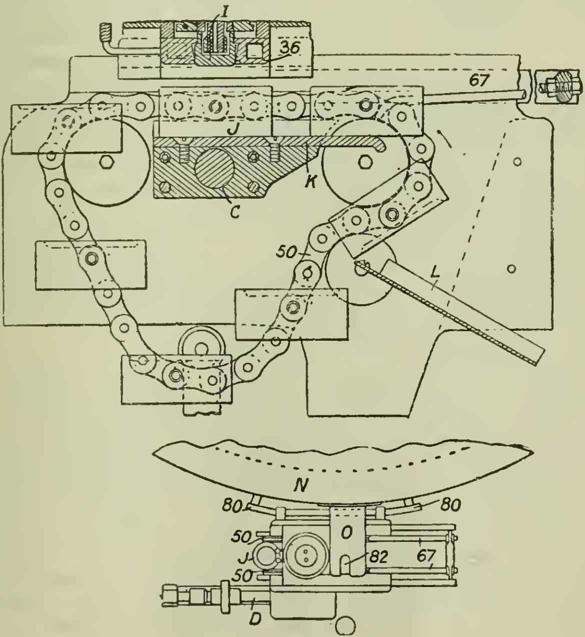


Fig. 197.

manufacture of pressed glassware. The machine is shown in plan in Fig. 197, hooked on to a rail, 80, in front of the hole in a tank furnace, *N*. A belt-driven shaft, *D* (Fig. 198), drives the main shaft, *C*, through worm gearing, 6, 7. The moulds, *J*, are hung at intervals between a pair of chains, 50 (Fig. 197), which are moved intermittently by cam-operated push rods, 67. Each mould, *J*, is charged by the gatherer, who inserts his punty through a hole, 82 (Fig. 197), in a shield, *O*, and passes on beneath the plunger, *I*, which descends during the interval of rest of the mould and presses the charge. The mould, *J*, then moves off the supporting plate, *K*, and travels with the chains, 50, as shown in Fig. 197, until it is tilted by striking a discharge shoot, *L*, down which the finished article slides. The plunger, *I* (Fig. 197), and follower ring, 36, are slidably mounted in a reciprocating cross-head, *G*, and are pressed downwards by a strong spring, 44, and a weaker spring, 46, respectively. The tension of these springs is adjusted by nuts, 48, and the height of the plunger, *I*, and follower, 36, is then adjusted by moving vertically in the cross-head, *G*, a ring, 45, against which the springs, 44, 46, abut. The ring 45 is then clamped by a tapered plug, 47. The plunger, *I*, and follower, 36, are water-cooled. Casings, *E*, *H*, are provided for the protection of the mechanism and the retention of lubricant. Cam-operated shears are provided to sever the charge as it hangs from the punty. The Specification states that the machine can be used in conjunction with an automatic gathering apparatus. H. G. C.

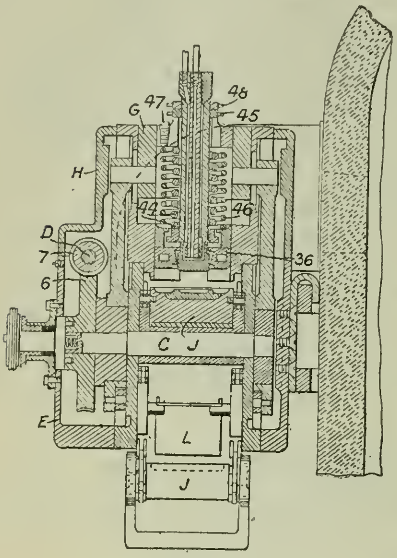


Fig. 198.

341. Machine for Blowing Small Electric Bulbs. H. E. Quackenbush and C. L. Quackenbush, assignors to General Electric Co. (U.S.A. Pat., August 12th, 1919, No. **1313205**. Filed May 13th, 1916, No. 97218).—This invention relates to a machine for blowing small electric lamp bulbs from a glass tube. Mounted above the base plate, 10, are two tubes, 14, which act as tracks, and on which are mounted the slidable carriage, 101, and the movable chuck. Two shafts, 38, 39, and a covering sleeve, 40, are mounted through the central part of the carriage. At the projecting ends of the shafts are double cranks, 43, which have the same throw as the cranks, 44, which are mounted at the outer ends of the chuck barrels, 27, 37. By this means, a tube of glass mounted in the two chucks receives a positive rotation, and is not subjected to any torsional strain. The two chucks are opened together by means of the two chains, 53, attached to the two bell crank levers, 52. The inner ends of the chucks are provided with rubber blocks, so as to make a cushion, against which the ends of the glass tube are pressed. Through the fixed chuck an air passage is arranged, enabling air under a small pressure to be delivered through the rubber block to the interior of the glass tube. The carriage on which the burners are supported is brought up to the part of the tube it is desired to heat, and when the tube is hot enough, a half-mould is brought up to one side of the tube and compressed air is admitted through the chuck The half-mould is adapted to facilitate the correct formation of the bulb, and also to act as a gauge of its diameter. When one bulb has been blown, the burner and mould carriage can be moved along to the next position at which it is desired to blow another bulb. S. E.

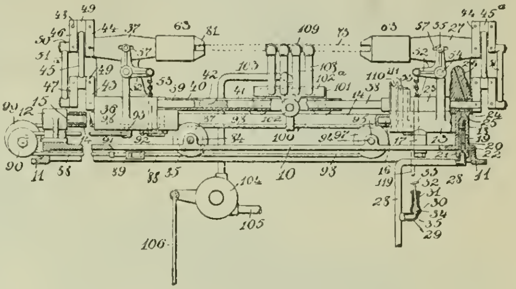


FIG. 199.

342. Mould for Blowing Bent-necked Bottles.

J. MACLUSKIE (Brit. Pat., March 24th, 1919, No. **139322**).—Relates to a mould for blowing bent-necked bottles. The body part, *a*, is of the usual two-part hinged type, and closes upon a disc, 6, projecting from the base-plate, 1. The neck, f^1, of the bottle is formed partly by the upper part, *i*, of the body mould, *a*, and partly by a top segment, *c*, which is hinged at 5 to one of the body segments, *a*. The gather is first placed in the mould, *a*, and partly blown, the blowpipe, *B*, being then drawn out and the top segment, *c*, closed. In a modification for machine use, the segment, *c*, is in three parts hinged together so as to form a neck mould, which is first inverted and used in conjunction with a parison mould to form a blank. The neck mould is then turned over and placed on the blowing mould, *a*, and the bottle completed. The neck is afterwards ground off as usual.

H. G. C.

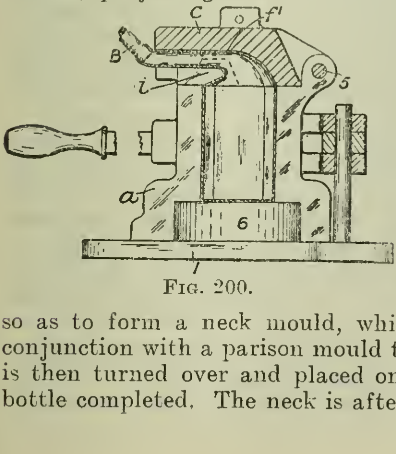


FIG. 200.

343. Pressing Plunger Mechanism. W. J. Miller (U.S.A. Pat., December 30th, 1919, No. **1326365**. Originally filed August 11th, 1917, No. 185647. Divided, and this application filed June 22nd, 1918, No. 241431).—Detailed methods are given for mounting a plunger in a pressing machine in such a way that it can easily be adjusted so as to centre properly with the mould.

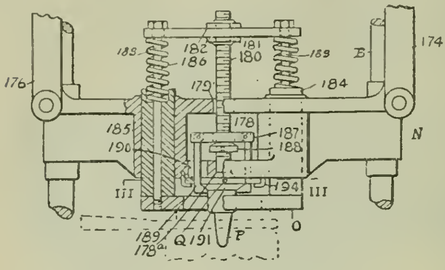


Fig. 201.

The sliding cross-head, *N*, which carries the plunger mechanism is provided with a transverse horizontal opening, 178. A threaded shaft, 180, passes through a hole in the upper part of the cross-head, and its lower end is screwed into the floor of the horizontal opening. The upper end of the shaft is fixed to a cross-bar, the ends carrying bolts, to which is attached a spring-pressed plate fitting on the top of the mould. A horizontal yoke is adjustably supported on the lower portion of the threaded shaft, and to its ends are pivoted two gripping fingers, which engage the bevelled flange of the plunger and keep it in place. The plunger is further secured in position by screwing up a ring, which is floatably supported from the cross-head.

The office of the spring plate is to engage resiliently the top of the mould as the plunger is depressed, and to lag behind the rising plunger, thus stripping the glass from the emerging plunger.

S. E.

344. Means for Conveying Ware to Lehrs. R. W. Niver, assignor to Owens Bottle Machine Co. (U.S.A. Pat., October 19th, 1920, No. **1356157**. Filed August 19th, 1918, No. 250424).—According to this specification, bottles are taken from a blowing machine and placed in an upright position on a conveyor table, 12, at a point, 13. An endless, horizontally rotating chain, 15, running on sprockets, 17, 18, carries at equal intervals a number of laterally extending hooks, 21. These hooks engage the bottles at 13 and carry them along the table until they are arrested by a stationary stop, 22. Here the hooks are pressed backwards approximately 90°, and thus are enabled to pass on, leaving the bottle standing. An extending arm, 24, on coming into contact with lugs, 26, on the hooks, returns them to their projecting positions.

Driven from the same shaft that drives the conveyor chain is a short, endless chain passing round the gear-wheel, 421, which carries an extending arm, 45. This arm is connected by a curved rod, 46, to a pusher, 48, so that for each rotation of the gear, 421, the pusher is reciprocated once. At the end of the push rod is a bottle-gripping device with spring arms, 52, so arranged that the first portion of the movement of the pusher rod closes the spring arms, thus gripping the bottle securely, while the latter part of its movement carries the bottle forward into the lehr. On the return movement, the gripper is first released and then the pusher is withdrawn. The trough, 88, which is rigidly attached to the end of the conveyor table, passes through a slot in the lehr door, 57. This door has an intermittent motion across the front of the lehr, and thus carries with it the conveyor table. When one row of bottles has been placed on the lehr pans and the conveyor table has come to the limit of its movement, a commutator automatically closes the circuit for the motor that operates the lehr conveyor, 111, and causes it to move forward a sufficient distance to allow another row of bottles to be placed thereon without coming into contact with those already in place. S. E.

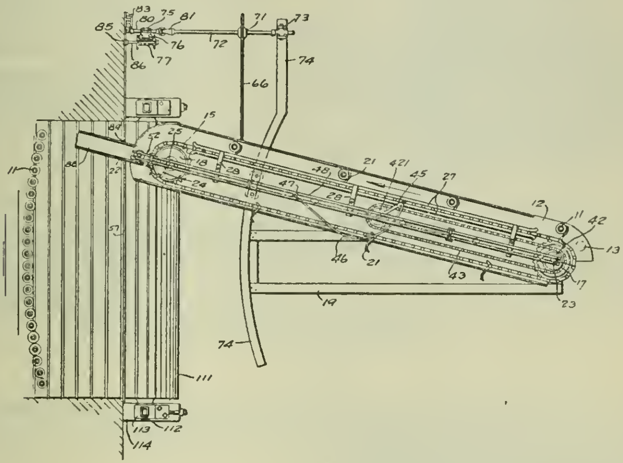


Fig. 202.

345. Automatic Conveyor and Lehr. W. S. Mayers (U.S.A. Pat., April 27th, 1920, No. **1338240**. Filed December 11th, 1917, No. 206666).—In this device the ware is taken hot from the moulds and quickly placed in a heat-insulating chamber, 1 (Fig. 203), from which it passes forward through the cooling sections, 2, 3, and 4. The walls of the chamber, 1, are made of refractory heat-insulating materials of sufficient thickness to reduce loss of heat by radiation. The walls of sections 2, 3, and 4 have less insulating properties than the walls of section 1. The cooling sections, 2, 3, and 4, are just large enough to house the upper run of the main conveyor and the largest ware to be annealed. Cold air is prevented from entering the cooling chambers by the seal, 14, which fits closely over the main conveyor bars and chains. At the bottom of the first section is the combustion chamber, 18, and between the two is a muffle plate, 19. The gas burner is placed under the rear end of this muffle plate, so as to provide means for heating the conveyor plates and for keeping the glassware hot while in the receiving chamber.

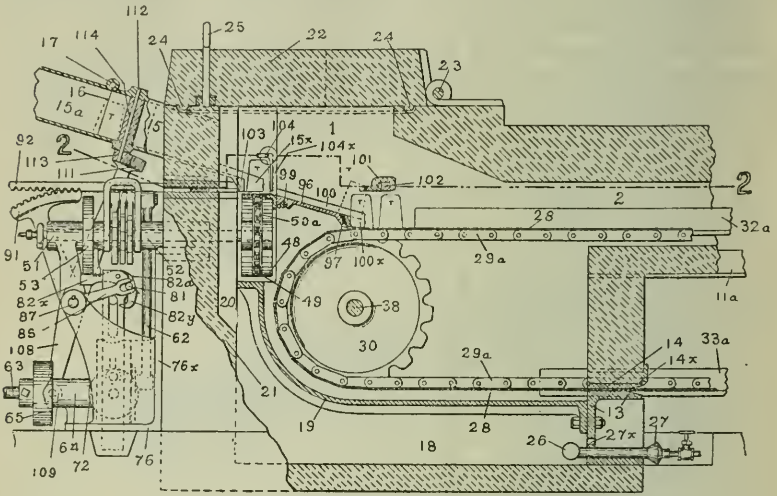


Fig. 203.

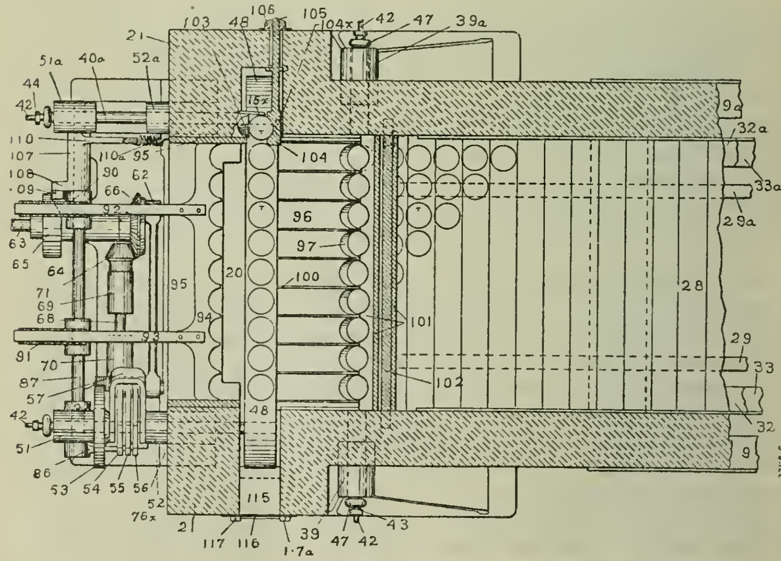


Fig. 204.

A metal feeding chute, 15, is fitted through the end wall of the receiving chamber, and is inclined at such an angle that the ware will just slide down it on to a small single-chain conveyor, 48, which runs across the front of the main conveyor. This cross conveyor has an intermittent motion, the extent of each movement being rather more than the width of the ware being annealed. This movement is timed to take place a short time after each article has been deposited on the conveyor from the chute, 15. A multiple pusher-bar is riveted to rock rods, 92 and 93, which mesh with segmental spur gears, 90*x* and 91*x*. These, in turn, are keyed to the rocking shaft, 87, so that when this shaft is rocked from its position of rest, the pusher-bar moves forward and pushes the ware from the cross conveyor on to the main conveyor. The speed of the lehr conveyor is controlled so that it moves forward a distance slightly greater than the diameter of the ware being annealed during the interval between the operations of the pusher-bar. S. E.

346. Conveyors for Glassware. J. L. Hiatt, assignor to Schram Glass Manufacturing Co. (U.S.A. Pat., March 23rd, 1920, No. **1334453**. Filed September 30th, 1918, No. 256198. Renewed August 9th, 1919, No. 316489).—This conveyor is designed for carrying glassware from moulding or blowing machines and discharging it into a lehr automatically.

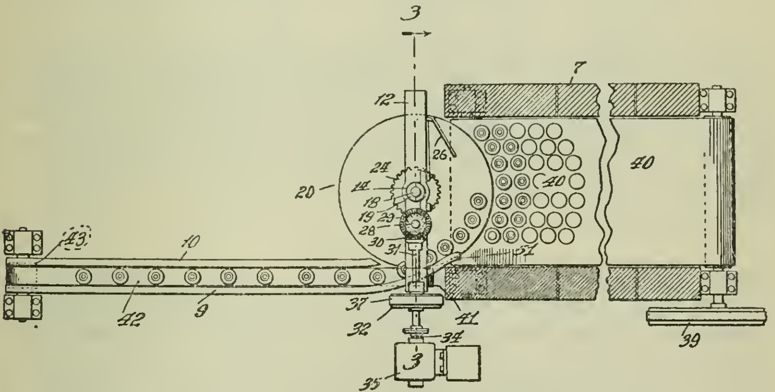


Fig. 205.

A horizontal frame with guide bars, 9 and 10 (Fig. 205), is erected in between the machine and the lehr, and over pulleys, 41 and 43, mounted at the ends of the frame, is passed a conveyor belt, 42. At the same level as the conveyor belt is a large horizontal table, 20, rotatably mounted on a vertical shaft, 18. Keyed to this same shaft, and above the table, is a gear wheel, 24, which meshes with and is driven by a smaller wheel mounted on the shaft, 28. Thus the table, 20, is continuously and slowly rotated.

The glassware is placed on the conveyor belt, which carries it towards the table, and the transfer to the table is made by the curved portion, 51 (Fig. 206), of the guide bar, 9. As the circumference of the disc, 20, has a slower speed than the belt, 42, the glass articles as they are transferred to the disc are packed closely round its edge.

The removal of the glass from the disc to the lehr pans, 40, is accomplished by the bent bar, 50, which is attached to the arm, 44. This arm is pivotally mounted on the sleeve, 25, and is operated at intervals by the lever, 53, which is secured to the arm, 44, at 54. At its other end is a link, 56, through which passes a stud, 55, attached to the disc, 57. As this disc rotates, the bent bar, 50, sweeps over the table, pushing the glass articles off into the lehr, and then returns to its initial position and remains at rest until another batch of glass articles is ready to be transferred to the lehr pans. S. E.

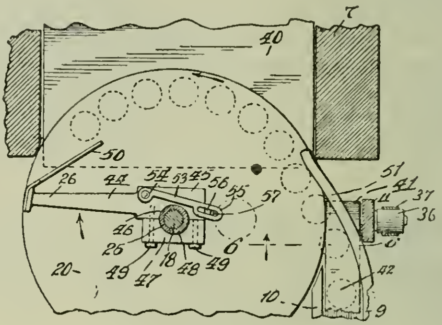


FIG. 206.

347. Glass-working Machine. F. L. O. WADSWORTH, assignor to Ball Bros. Glass Co. (U.S.A. Pat., December 30th, 1919, No. **1326235**. Filed April 24th, 1914, No. 834233).—The invention is particularly intended for use with flow feeds, whereby a speeding-up is secured by reducing the time during which the feed is interrupted in order that a filled mould may be replaced by an empty one.

In the machine, the moulds, 4, rotate in a vertical plane about a horizontal shaft, 6, which is rotated intermittently to move the moulds from one station to the next. During the greater part of its movement, a mould moves in a circle about the axis of the shaft, 6, but from station VII to station I it moves vertically upwards. During this upward movement it receives a charge from the flowing stream, and is moved from beneath the stream, passing from station I to station II when the stream is severed by the shear blades, 23, 24. However, since there is always an empty mould beneath the one that is being charged, the interruption of the stream during shearing is only necessary while the filled mould is moving through a distance about equal to half its diameter.

The moulds are made with trunnions, which are journalled in blocks, 10, that slide in slotted arms radiating from the hub of the rotating frame. The trunnions also carry rollers which engage, during the rotation of the frame, the edges, 16, of plates fixed alongside the frame, and with vertical guides, 18. At the various stations the glass in the moulds may be subjected to pressing, blowing, etc., and they may be inverted by fixed racks, 38, at station V to discharge the finished ware.

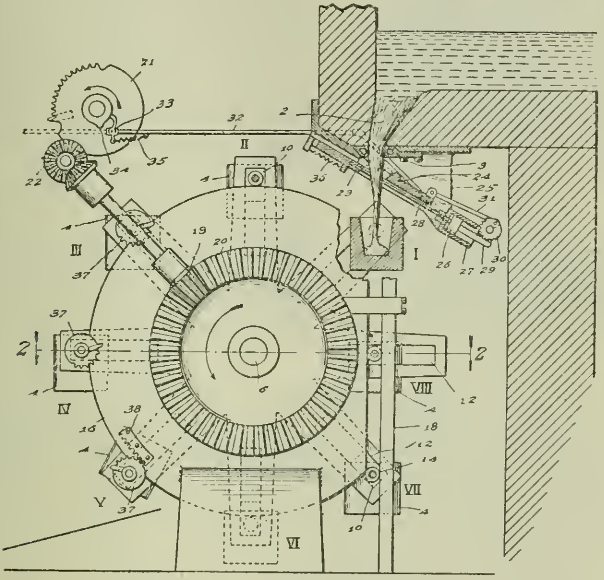


Fig. 207.

The stream of metal flows from the tank, 1, through a water-cooled ring, 3, and is severed at the proper intervals by blades, 23, 24, moved by means of a piston, 26, in a cylinder, 27. The frame is rotated intermittently by an interrupted gear, 21, and this gear also actuates a valve, 33, that admits air or steam to the piston, 27, by means of a cam, 34, in its driving shaft. G. D.

348. Glass-drawing Apparatus. W. Westbury (U.S.A. Pat., December 30th, 1919, No. **1326241**. Filed October 3rd, 1917, No. 194496).—This specification describes in a little more detail the drawing apparatus which is the subject of U.S. Pats. 1307943 and 1307946,* and claims the device for water-cooling the gear used for supporting and lifting the pots. G. D.

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* This vol., Abs. No. 65.

349. Drawing Glass Cylinders. H. Wade, assignor to the Empire Machine Co., Pittsburgh, Pa., U.S.A. (Brit. Pat., November 7th, 1919, No. **140029**).—Relates to the automatic control of air admitted to the drawn glass cylinder during the formation of the cap. The air is vented from a valve, 12, having a large port and a small port. During the first 22 inches of the draw, while the cap is being formed, a weight, 26, attached by a cord, 28, to the valve lever, 18, keeps the small port open. A catch, 35, then strikes a projection, 38, and releases a heavier weight, 25, which pulls the lever, 18, to the right, and so opens the large vent port. This action reduces the air pressure in the cylinder for the main portion of the draw.

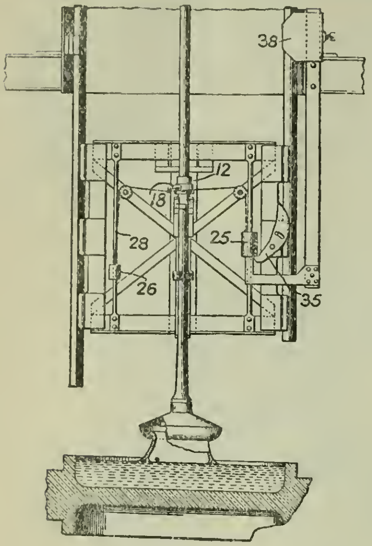


Fig. 208.

H. G. C.

350. Drawing Glass Cylinders. C. Donaldson, J. J. Bloxsom, and J. K. Brooks (U.S.A. Pat., July 29th, 1919, No. **1311804**. Filed April 26th, 1917, No. 164774).—The invention consists of a

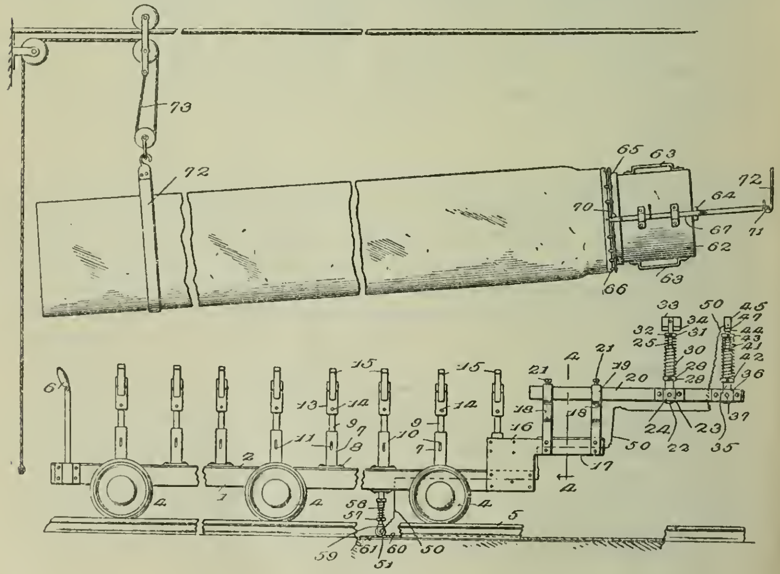


Fig. 209.

"horse" for supporting a cylinder while it is being cut up into suitable lengths for flattening, and comprises also a device for reheating the bait. The "horse" comprises a platform, 1, mounted to run on rails, 5, and provided with a number of spring-supported saddles, 15, for carrying the cylinder. The bait is supported when the cylinder is on the "horse" by spring-supported members, 33, mounted on bars projecting from the front end of the "horse."

The bait consists of a cylindrical body, 62, having its upper end closed and at its lower end a flange, 65. A ribbon, 66, of high electrical resistance is attached to, but insulated from, the flange, 65, and it is this ribbon to which the glass adheres. When the cylinder and bait are lowered on to the "horse," electrical leads, 67, connected with the ribbon rest in holders, 45, which are connected by wires, 50, with conductor rails, 60. Thus, as soon as the cylinder is placed on the "horse," the bait is electrically heated so as to maintain it at the desired temperature. G. D.

351. Making Plate Glass. H. K. Hitchcock (U.S.A. Pat., June 24th, 1919, No. **1307357**. Filed September, 26th, 1913, No. 792011).—The invention consists of mechanism for automatically discharging a definite quantity of metal from a tank furnace on to a rolling table and distributing it evenly in front of the roller, the discharge of the metal being controlled by the movement of the table itself beneath the spout through which the glass is delivered. The gathering and discharging device is shown in cross-section in Fig. 210. The tank furnace, 1, has an extension, 2, through which the hot gases pass to a flue, 14, leading to the stack, and this extension contains a dome-shaped shell, 4, which rests on the floor, 6, of the extension. The chamber, 4, is elliptical in plan and has a neck, 7, which is connected with an air pipe, 8. Gutters, 10, 11, are formed in the floor, 6, beneath the opposite ends of the chamber, 4; the gutter, 10, communicates by a passage, 10^a, with the body of the tank, and the gutter, 11, passes under the edge of the chamber and joins with a spout, 12.

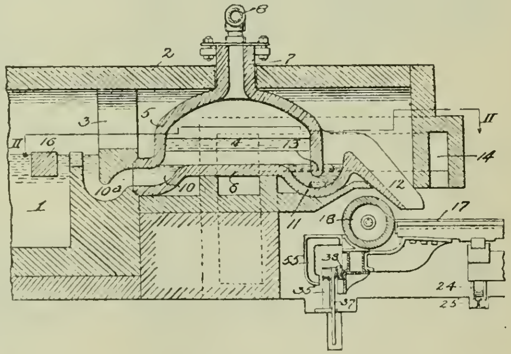


Fig. 210.

The casting table, 17, is mounted on wheels, 24, which run on rails, 25, arranged across the front of the tank, the inner edge of the table passing beneath and close to the lip of the spout, 12.

In use, air is exhausted from the chamber, 4, through the pipe, 8, thus causing metal to flow from the tank into the chamber. After the desired quantity has entered the chamber, air under pressure is admitted through the pipe, 8, thus discharging the metal out of the spout on to the table, 17. At the same time, the table is moved along the rails so that the metal is deposited along the edge in front of the roller, 18. In order to make the machine automatic, the device for exhausting the air from, and compressing it in, the chamber, 4, is controlled by the table, so that movement of the table in one direction charges the chamber with metal, and in the other direction causes discharge of the metal. The device consists of a cylinder with its open end immersed in water. The pipe, 8, leads into the interior of the cylinder, so that when the cylinder is raised out of water, air is sucked from the chamber, 4. Conversely, lowering the cylinder into the water compresses air into the chamber. The cylinder is connected by a cable with a lever moved by the table. Details of the roller gear are given in the specification. G. D.

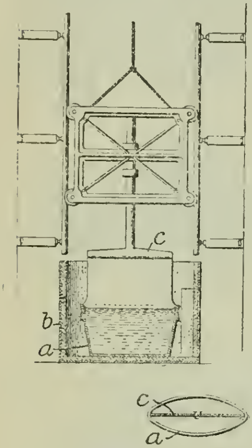


Fig. 211.

352. Drawing Sheet Glass. Virginia Plate Glass Corporation, U.S.A. (Brit. Pat., April 15th, 1920, No. **141737**).—The pots, *a*, from which sheet glass is drawn are elliptical in plan and may taper downwards. The bait bar, *c*, is about equal in length to the major axis of the pot. The drawing chamber, *b*, is kept at the desired temperature by gas burners. H. G. C.

353. Drawing Sheet Glass. A. L. Forster, West Smethwick, Staffordshire (Brit. Pat. No. **135697**. January 28th, 1919, No. 2017).—In drawing apparatus of the kind in which sheet glass, *c*, is drawn up between endless asbestos belts, *d*, rows of short spring-pressed rollers, *l*, are employed to improve the grip of the belts, *d*, on the glass, *c*. By using short rollers, *l*, breakage of the sheet, *c*, is said to be avoided. One of the bottom rows of rollers may be replaced by a flat plate, *r* (Fig. 212), to assist in flattening the drawn sheet. Chain-mail may be incorporated in the belts, *d*, to increase their strength.

H. G. C.

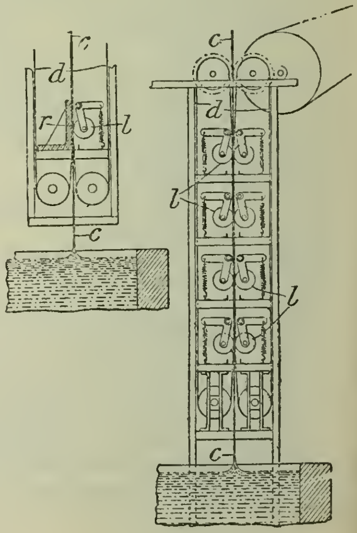


Fig. 212.

354. Making Sheet Glass. T. J. McCoy, Shinglehouse, Pennsylvania, U.S.A. (Brit. Pat. No. **134807**. October 11th, 1918, No. 21788/19). — Relates to apparatus for the production of sheet glass by allowing molten glass, 3, to flow continuously over a dam, 5, from a tank, 1. The front face of the dam, '5, is inclined slightly backwards, so that the glass sheet readily leaves it and is carried into the lehr, 24, by a conveyor, 23. The side walls, 4, shown in horizontal section in Fig. 213, are formed with projections, 10, which deflect the hot gases from burners, 11, on to the edges of the sheet, 3, and so prevent them from becoming unduly cooled. The temperature is also regulated by a damper, 8, and movable top and front stones, 6 and 7, respectively. H. G. C.

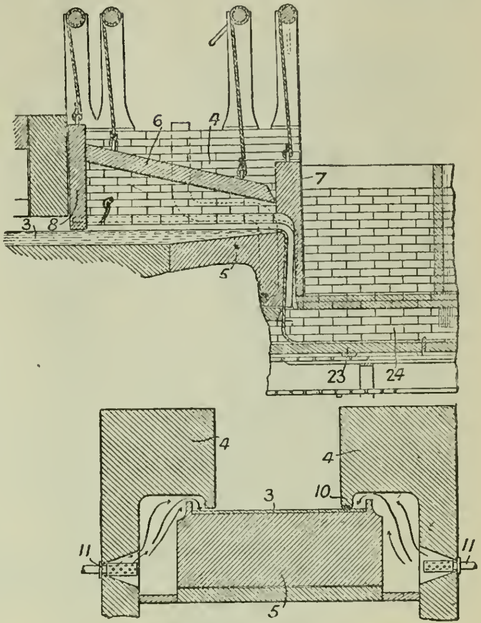


FIG. 213.

355. Drawing Sheet Glass. M. J. Owens (U.S.A. Pat., June 6th, 1920, No. **1327405**. Filed November 18th, 1918, No. 263024).—Relates to the process of drawing glass in flat sheets, and consists of means whereby the temperature of the metal at the drawing point can be regulated to suit the thickness of the sheet being drawn. The tank, shown in longitudinal vertical section in Fig. 214, consists of the usual melting chamber, 1, a refining

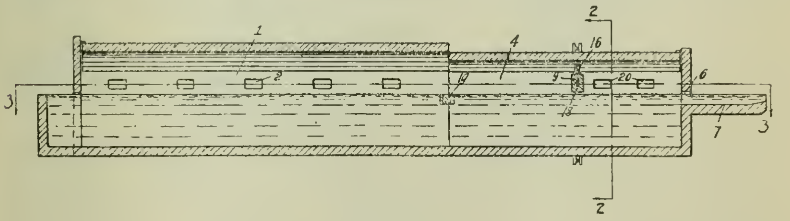


FIG. 214.

chamber, 4, separated from the chamber, 1, by a floating bridge, 19, and a shallow cooling chamber or trough, 7, over which the metal passes into a drawing-pot. The width of the refining chamber, 4, is only slightly greater than the width of the sheet being drawn, in order to prevent the accumulation of cooler metal along the sides of the chamber.

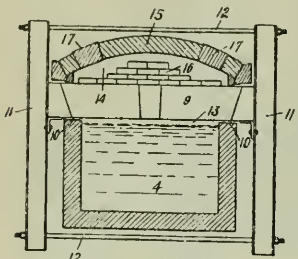


Fig. 215.

It is found that the temperature of the metal in the end of the chamber, 1, towards the drawing-pot should be varied to suit the thickness of the sheet being drawn, as a lower temperature is required when drawing thick sheet than when drawing thin. The required regulation of temperature is accomplished by building across the chamber, 4, a "jack arch," 9, the lower surface of which is separated from the surface of the metal by a narrow space, 13. The opening, 14, between the top of the "jack arch" and the crown, 15, of the chamber can be varied by means of bricks, 16, placed in the arch through an opening, 17, in the crown. The "jack arch," 9, restricts the flow of hot gases from the chamber, 1, to the end of the chamber, 4, and by varying the space, 14, by means of the bricks, 16, the temperature of the metal in the drawing-pot can be regulated to suit the conditions of working.

G. D.

356. Cutting or Severing Glass Bars or Tubes. Libbey Glass Co., Toledo, Ohio, U.S.A. (Brit. Pat., March 17th, 1920, No. **140440**).—Relates to apparatus for continuously drawing a rod or tube of glass from a forming apparatus, and successively severing it into sections or predetermined lengths. The action of the cutting tool is illustrated in Fig. 216, the path of the rotating tool or disc, 76, relatively to the work, *A*, being indicated in dotted lines. The tool moves forward at the same speed as the work, first downwards into contact and then upwards therefrom, as shown by

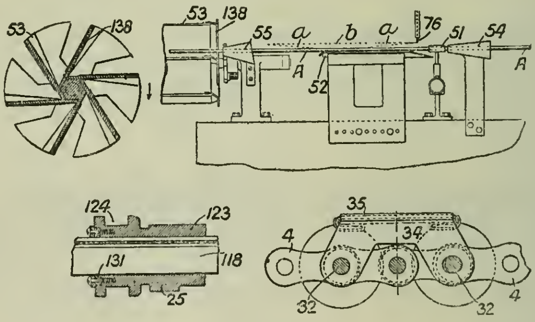


Fig. 216.

the line *a*, the line *b* indicating the non-cutting return stroke. The action of the cutter is stated to be two-fold: first, to groove or abrade the work, and, secondly, to set up a localised heating, and consequent strain, within the material at the point of contact. The section thus grooved and weakened is subsequently broken off from the main body of the rod or tube by the action of plates or vanes, 138 (Fig. 216), on a rotating delivery wheel, 53 (Fig. 218). The general arrangement and operation of the machine is as follows. The work, *A* (Figs. 217 and 218), advancing from the furnace or other source of supply, passes between two horizontal spring-mounted guide-rolls, 3, and thence between two sets of feed chains, 4, 4. These are driven at the same speed through upper and lower driving shafts, 8, 6, and spur gearing, 44, 45, 48, 49, from a motor, 43. The upper shafts, 8, 9, are mounted

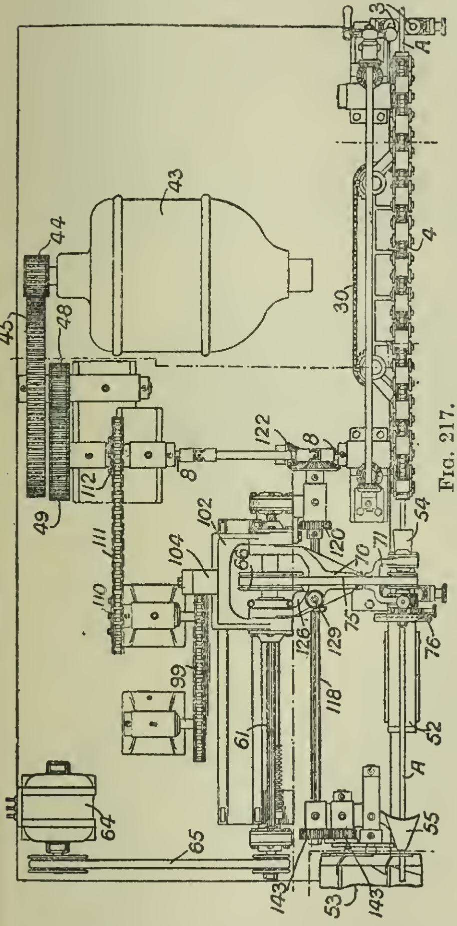


Fig. 217.

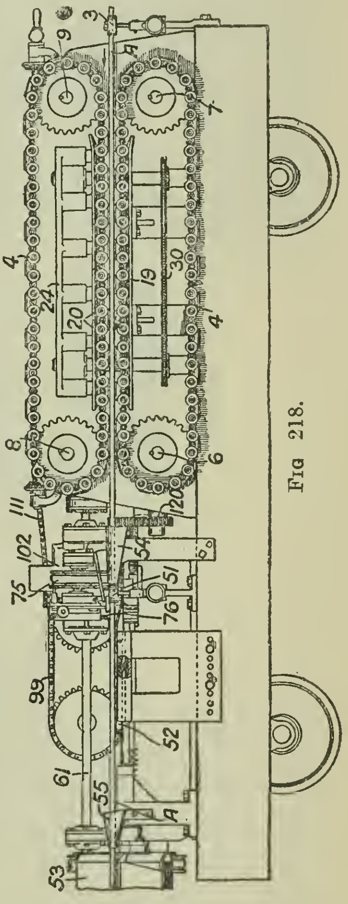


Fig. 218.

so that they can be adjusted vertically relatively to the lower shafts, 6, 7. The chains, 4, are held in yielding contact with the work by means of spring-pressed upper plates, 20, and a stationary platform, 19, below. The pressure of the plates, 20, can be simultaneously adjusted by means of a sprochet-chain, 30 (Fig. 218), which raises or lowers the supporting frame, 24. The work is actually gripped between pads, 35 (Fig. 216), mounted on U-shaped chairs, 34, carried on the links, 32, of the chains. The work passes from the chains through a guide, 54 (Fig. 218), and thence between guide-rollers, 51, similar to the guide-rolls, 3. It next passes under the cutter disc and over a spring-supported table, 52, and, after being acted upon by the cutter, travels past a guide-member, 55, into one of the pockets of the breaking-off and delivery wheel, 53. The cutter, 76, is rotated by a motor, 64 (Figs. 217 and 219), through belt gearing, 65, 66, 75. It is mounted in a bearing-fork, 71, which is adjustably connected to

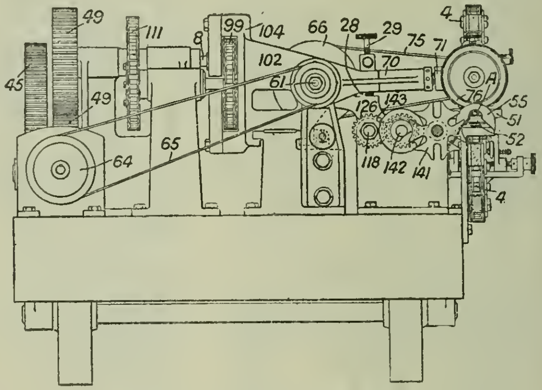


FIG. 219.

a slide head, 70 (Fig. 217), so as to permit tensioning of the belt, 75. The slide head, 70, is traversed along a shaft, 61, at the same speed as the work by means of an endless chain, 99, driven through gearing, 110, 111, 112, from the main motor, 43. A transverse stub shaft is mounted on the chain and carries at each end rollers, which engage in a groove formed in the vertically elongated boss, 104 (Fig. 217), of a yoke or slide frame, 102, which is mounted to slide on the shaft, 61, and carries the slide head, 70. The downward movement of the cutter to effect the actual cut is obtained by means of a cam, 123 (Fig. 216), having a peripheral cam surface, 125, and splined on to a shaft, 118 (Fig. 217), which is driven through gearing, 120, 122, from the drive shaft, 6, of the feed chains. An arm, 126, mounted on the shaft, 61, engages with a peripheral groove, 124, on the cam, 123. A roller on the arm, 126, contacts with the cam surface, 125, and as the latter is rotated the arm 126, is rocked about the shaft, 61, and imparts a similar rocking movement to the slide head, 70, through a stud, 28 (Fig. 219), and thence to the cutter. Fixed at each end of the cam-wheel, 123, are cleaning gaskets, 131 (Fig. 216), which project into the spline grooves in the shaft, 118, and free them from accumulated dirt during each traverse. The cutter may be adjusted vertically with respect to the work by means of a screw, 129 (Fig. 217). A pair of work-guiding fingers are mounted by the side of the cutter disc and hold the work against any transverse movement during the cutting action. The breaking-off and delivery-wheel, 53, is rotated intermittently by Geneva gearing, 141 (Fig. 219), driven through spur gearing, 142, 143, from the shaft, 118. H. G. C.

357. Device for Marking Glass Preparatory to Cutting.

H. D. Fitzpatrick and Fours et Procédés Mathy Soc. Anon., Liège, Belgium (Brit. Pat., May 10th, 1919, No. **140257**).—An appliance for marking various lines, curves, etc., on glass and the like preparatory to cutting, comprises a central table, and, arranged round it, a series of marking devices having pencils for marking the lines and curves in coloured liquid. The table is rotatable, but may be fixed at will in the desired positions. As shown, the table, 3, for supporting the object, 22, to be marked is rotatably mounted on a vertical pin, 2, in the centre of the frame, 1, which carries the marking devices, 67, 89, 94, etc. On the table, 3, are three radial slides, 5, having rubber-covered pins, 6, for clamping the object, and operable simultaneously to centre it, after the

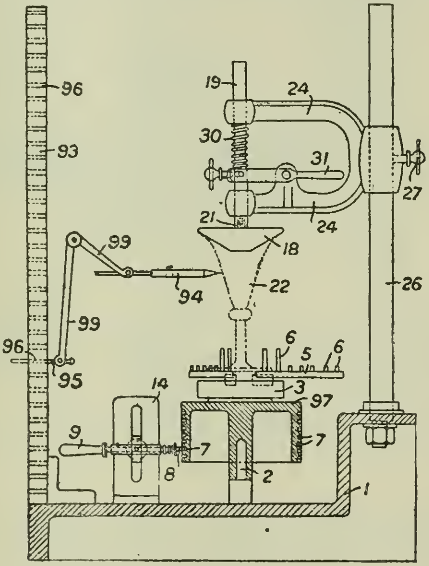


Fig. 220.

manner of a chuck. A drum, 97, secured to the table, 3, has a series of horizontal rows of holes, 7, at different distances apart, any of which may be engaged by a pin, 8, for locking the table. The pin, 8, is adjustable in height to engage any one of the rows of holes, 7, on a bracket, 14, and is spring-pressed into engagement, after withdrawal by its operating handle, 9. A centring and steadying clamp for the upper end of the object comprises a conical buffer, 18, rotatably mounted at 21 on a rod, 19, slidably mounted in a bracket, 24, adjustably fixed by a screw, 27, on a post, 26. A lever, 31, is provided for lifting the rod, 19, and buffer, 18, which are pressed downwards by a spring, 30. The various marking devices are arranged round the table, 3, on supports, 36, 59, 49, 68, etc., and each is provided with one or more pencils or pens for applying a coloured liquid. These pencils, as shown at 67 (Fig. 222), each comprise a pointed tube, 67, having a ball valve closed by a spring, 46, and opened when the pencil is pressed against the object, 22, by a needle point, 47, on the ball projecting through the nozzle or opening. For marking lines in vertical planes, a pencil, 38, is carried by a handle portion, 39, 40, pivotally mounted, and also slidable in a radial direction on a bracket, 36, the pivotal support, 43, being adjustable in a vertical slot. Concentric circles may be traced on horizontal or approximately horizontal surfaces of the object, 22, by a series of depressable vertical pencils, 53, adjustable in slots, 51, in an horizontal arm, 48, adjustable vertically and angularly on a post, 49. Horizontal circles may be marked on inclined or vertical surfaces of the object by a series of pencils, 67, slidable in brackets, 61, adjustable vertically and angularly on a slotted bracket, 59. Springs, 66,

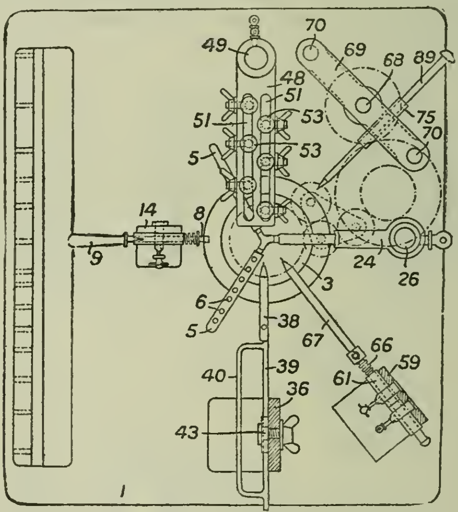


FIG. 221.

retract the pencils, any of which may be pressed inwardly to engage the object. Helical lines are marked by a pencil, 89, in a carrier, 75, movable vertically in a bracket, 69, 70, and engaging a helically-grooved shaft, 68, journalled in the bracket. The shaft, 68, is geared by variable and reversible gearing, shown in Fig. 222, to a wheel, 88, on the table, so as to rotate the table, 3, and object, 22, when the carrier, 75, is moved up or down. Arcs of circles and other curves may be marked by a pencil, 94 (Fig. 220), on a jointed compass or carrier, 99, pivoted to a pin, 95, which may be pivotally engaged in any one of a series of horizontal holes, 96, in a vertical plate or bracket, 93. The curves are made by pressing the pencil, 94, against the object, and at the same time rotating the compass about the pin, 95. H. G. C.

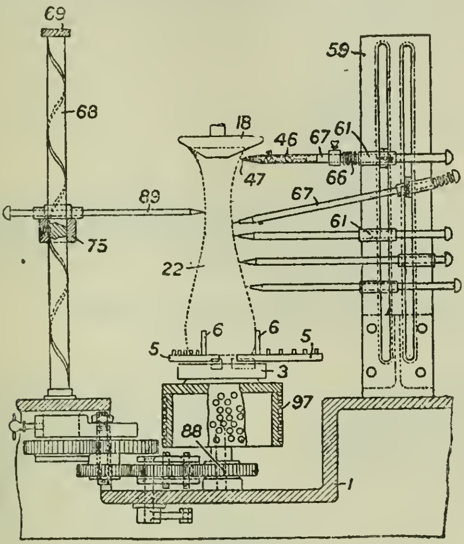
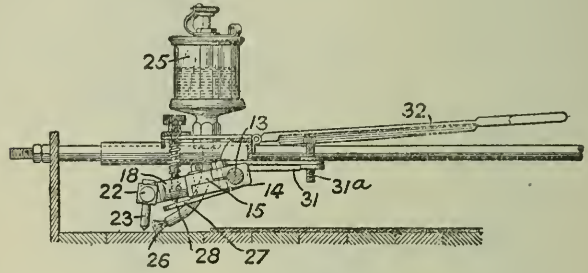


FIG. 222.

358. Cutting Sheet Glass. J. WATERLOO, assignor to EMPIRE MACHINE Co., Pittsburgh, Pa., U.S.A. (Brit. Pat., February 17th, 1920, No. **139189**).—In glass-cutting apparatus, in which a stationary sheet of glass is cut by a number of cutters mounted on a traversing carriage, means are provided for resiliently depressing the cutters when in action and for raising them when the cutter carriage is moved into position for a subsequent cut. An improved mounting for a cutter is also described. The apparatus may form an attachment for existing glass-cutting tables. A sheet of glass is passed over a table, 2, which may be provided with rollers, 3, into the cutting position, where it is engaged by gauges, 8. It is then cut transversely by a number of cutters mounted on a carriage, 9, adapted to be moved across the glass on rods, 5, by a handle, 32. Each cutter, 23 (Fig. 223), is slidably adjustable in an angularly adjustable shaft, 22, carried by a member, 18, angularly adjustable around an intermediate member, 15, secured to a member, 14, clamped to a spindle, 13, mounted freely for oscillation in the carriage. An adjustable spring-pressed pin, 28 (Fig. 223), bears on an arm, 27, secured to the spindle, 13, to depress the cutter normally, but it is adapted to be raised when the carriage is moved back into position for a subsequent cut by depression of the handle, 32, acting through a bolt, 31^a, carried by an arm, 31, secured to the spindle, 13. Lubricant is passed from oil cups, 25, to the glass immediately in advance of the cutters by means of wicks, 26.

FIG. 223.



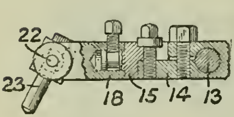


FIG. 224.

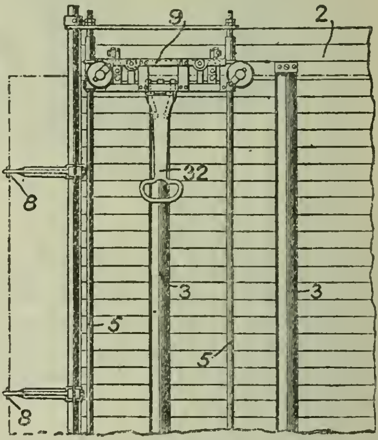


FIG. 225.

A further device by the same inventor is as follows:—

(Brit. Pat., February 17th, 1920, No. **139190**).—Relates to a machine for both cutting sheets of glass and for breaking them along the line of cut, and comprises a work support and feed of the endless conveyor type provided with transverse cleats of adjustable length, affording an edge over which the cut strips are severed by the bending action of a breaker device. The work is kept down on the conveyor in its passage under a stationary cutter by presser rolls disposed on each side of the cutter, and delivery and stacking devices are provided for the cut sheets. The conveyor may consist of two belts, 4, driven from a motor, 14, and to which are secured a series of cleats, 5 (Fig. 226), having reduced ends, 6, and some of which are provided with adjustable pallets, 7, furnishing an adjustable edge, over which the cut strip is severed by a breaker roll, 46. This roll, preferably of wood, fibre, etc., is transversely adjustable on a rod, 49, carried by a rod, 51, trunnioned at 53 in the fixed support, 18, and carrying a weight, 56. The conveyor is provided at intervals with raised cleats, 13, which serve to raise momentarily the breaker roll, 46, its subsequent descent under the action of the weight, 56, serving to detach the cut strips. The cutting or scoring tool, 40, is pivotally mounted in the support, 18, and bears on the work resiliently under the action of a spring, 42. Pairs of presser rolls, carried by pivoted arms depressed under the action of springs or weights, are disposed on each side of the cutter to control the work in its passage through the machine. The cut strips are received by a belt, 58, and conveyed to a stacking chair, 62, supported by a spring, 64, adapted to be adjusted so that the chair is depressed the width of a glass sheet as each is collected thereon. H. G. C.

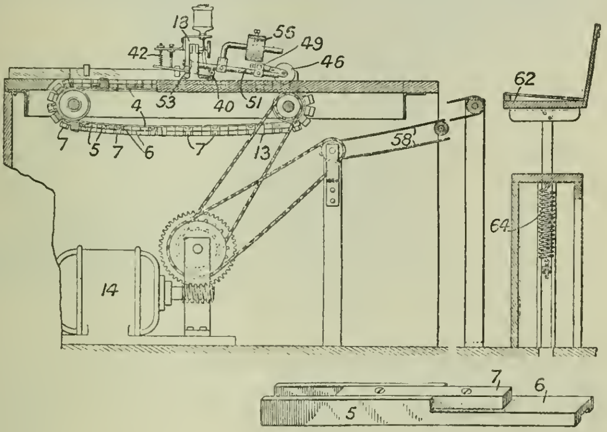


Fig. 226.

359. Cutting-machines for Glass. Empire Machine Co., Pittsburgh, Pa., U.S.A. (Brit. Pat., February 17th, 1920, No. **139188**).—Relates to a machine for cutting rectilinearly sheet glass fed beneath stationary cutters by an endless conveyor. The conveyor may consist of two belts, 5, to which are secured slats, 6, forming a continuous supporting surface for the glass, which is adjusted thereon against abutments, 16, on the conveyor and side gauges, 17, on the table, 2. The conveyor may be driven, as shown, by a treadle-controlled motor, 12, and its edges are supported by angle irons, etc., secured to the table. Each cutter, 26, is mounted on a carrier, 22, transversely adjustable on a vertically adjustable bar, 19, and bears with adjustable resiliency on the work. Pivotal adjustment is provided for the cutter in its holder. The glass is supplied, immediately in advance of the cutter, with lubricant from a cup, 32. A resiliently-mounted roller may be provided to press the work down on to the carrier. In a modification the carrier is moved by hand, and may work over adjustable drums provided with ball bearings. The machine may be provided with an additional conveyor for the removal and inspection of the cut sheets. H. G. C.

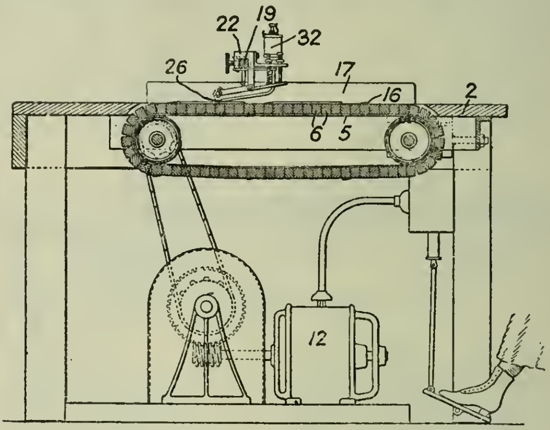


Fig. 227.

360. Glass Gathering Machine and Process. J. O. Jensen and J. Henle, assignors to J. O. Jensen Co. (U.S.A. Pat., May 27th, 1919, No. **1304568**. Filed November 21st, 1917, No. 203142).—This machine is designed to operate a gathering punty in a way very closely approximating the motion of a punty during hand gathering. The nose of the punty is advanced into the furnace, and partly submerged in the molten glass. While partly submerged, it is rotated and pushed forward so as to localise the bulk of the gathering at the forward end of the punty. On being lifted from the surface of the glass, the punty is drawn slightly to the rear in order to form a tail to help the gather to enter the mould easily, and then carried slightly to one side, so that when the gather breaks away from the main bulk of glass, the strand which has been drawn out falls to one side of the gathering point, thus minimising the tendency to form blisters and streaks. The punty is withdrawn rapidly from the furnace and swung laterally over the delivery point, and then lowered over the mould. The gathering is severed and the punty rotated through one-half a revolution, so that the cut-off end comes to the top of the glass remaining on the end of the punty.

Fig. 228 shows a side view of the machine. The punty, 21, with a clay nose, is clamped at 22 to the punty operating rod, 23. The cam groove, 33, times and controls the longitudinal motions of the punty. The cam groove, 34, causes and controls the vertical tilting motions, while the groove, 35, controls the lateral swinging movements. The punty is rotated by means of the manipulator rod, 23, which is feathered within a tubular sleeve, 46, mounted for rotation in a supporting bracket, 47. The sleeve, 46, serves as

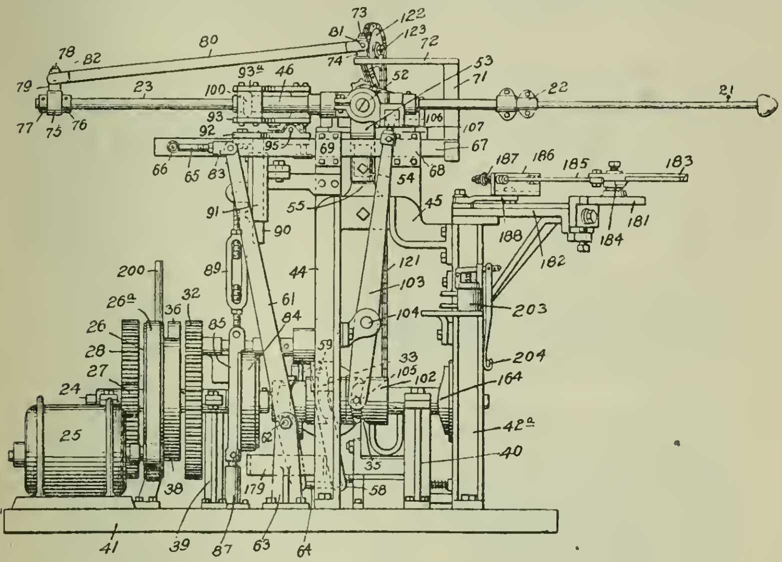


Fig. 228.

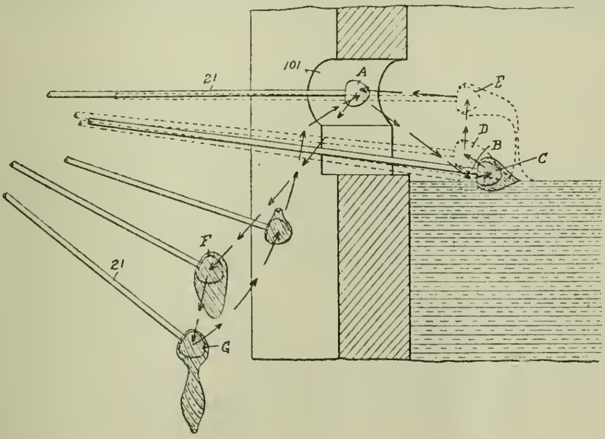


Fig. 229.

a universal support arranged to swing about two axes at right angles to each other. The point at which these axes intersect lies in the axis of the punty rod, and about this, as centre, the punty has universal movement.

Fig. 229 shows diagrammatically the movements of the punty in gathering and delivering a gob of glass. S. E.

361. Making Wire Glass. R. S. Pease (Assignor to Pittsburg Plate Glass Co.) (U.S.A. Pat., March 18th, 1918, No. **1259772**. Filed June 21st, 1912, No. 705032).—Wire glass is made by drawing the glass in a cylinder surrounding the wire and then flattening the cylinder to embed the wire in the walls of the cylinder. Fig. 230 shows in cross-section a doghouse, 1, containing the metal from which the cylinder is drawn, and having beneath it an airtight chamber, 1^a, supplied with air under pressure for the drawing. The wire strip, 4, which is stored in a roll in the chamber, 1^a, passes upwards through a slot, 5′, in a standard, 5, built up from the bottom of the doghouse. The wire and glass are drawn upwards by conveyor belts, 19, mounted on carriages, 15, 16. The belts are driven by motors, 20, and the carriages are mounted on rails, 17, so that they may be moved away from the drawing opening, 2.

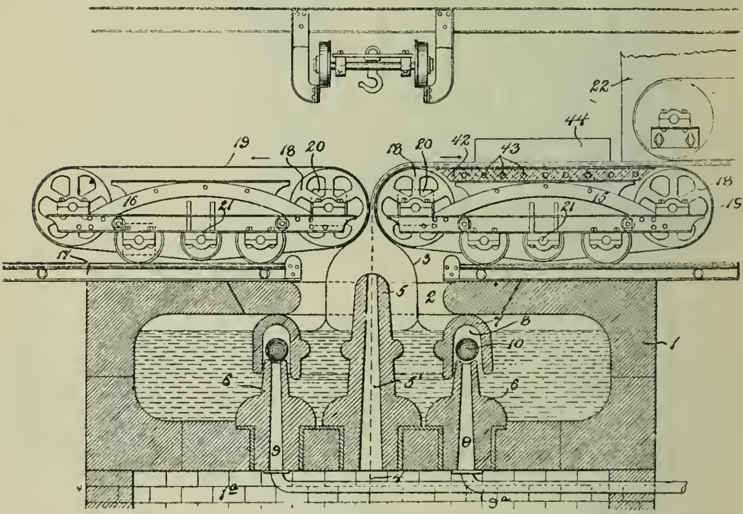


Fig. 230.

In commencing operations, an oval bait is lowered into the metal so as to surround the standard, 5, and at the same time the wire is attached to hooks carried by the bait. The bait is now raised, thus drawing a flat-sided "cylinder" of glass surrounding the strip of wire mesh. When the bait is drawn upwards a sufficient height, the carriages are run into the position shown, thus flattening the cylinder. The bait is laid on a belt and is carried away to the right. The drawing then proceeds continuously, a cylinder, 3, being formed, then flattened on to the wire, 4, and the complete sheet being conveyed through a lehr, 22. A floating ring, 7, surrounds the standard, 5, and protects the cylinder, 3, from the heat and flames in the doghouse. The truck, 15, is provided with steam pipes, 43, to prevent cooling of the sheet before it reaches the lehr. G. D.

362. Making Glass Letters for Signs. Eugene C. Gmelin (U.S.A. Pat., December 23rd, 1919, No. **1325785**. Filed June 19th, 1916, No. 104488). — The specification describes a method of making letters for display signs in which the letters appear in relief on the surface of a sheet of glass. The sheet of glass is placed on a die plate, 21, which is provided with grooves or depressions in the form of a letter, and the die is then placed in a furnace to soften the glass. The furnace consists of a flat bottom, 10, and a semi-circular arch, 9, and is heated by a row of burners, 12, on each side. When the glass is soft and commences to sag into the grooves of the die plate, the workman presses it completely into the grooves with a small male die fixed to a handle, 26. The die with the finished letter plate thereon is removed to a chamber, 27, beneath the furnace and allowed to cool slowly. G. D.

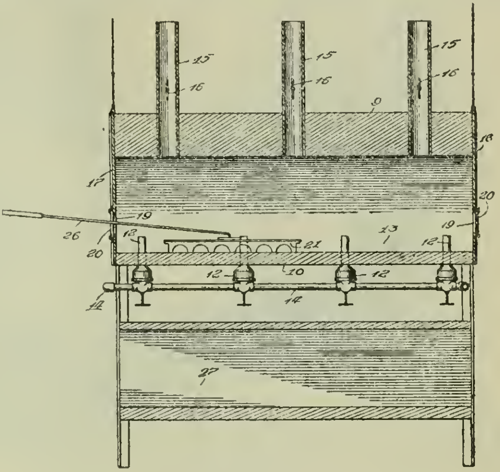


Fig. 231.

363. Apparatus for Feeding Molten Glass. B. D Chamberlain, assignor to the Empire Machine Co. (U.S.A. Pat., February 19th, 1918, No. **1256979**. Originally filed June 2nd, 1911, No. 630944).—This invention consists of apparatus for feeding metal in definite charges, shaping each charge into a parison, and affixing the parison to the end of a blowpipe, thus dispensing with gathering and marvering. The invention is particularly intended for use with a blowing machine, which appears to be the type described in Brit. Pat. 16794/1910. In this machine the blowpipes are automatically inserted in the tank to gather the metal, and the gather is marvered and blown automatically. As shown in Fig. 232, the device consists of a tank extension, *A*, in the bottom of which a hole, *B*, is formed. The metal runs through *B* in a continuous stream, and is received in a parison mould, *E*, supported by a frame, *C*, *D*, which is free to oscillate on a vertical pin, A^3. The stream of metal is cut off at suitable intervals by a rotary knife, *H*, having cutting edges, which co-operate with a cutting edge, *G*, fixed to the standard, *D*. Both the knife, *H*, and the cutter, *G*, are hollow, and may be heated or cooled by circulating suitable fluid through them. The parison mould, *E*, has trunnions, which are journalled on the ends of a lever, *F*, pivoted on the arm, *C*, and by moving this lever, the mould, *E*, can be turned on its side, as shown in dotted lines, with the mould space facing outwards. A forked guide, *m*, on the top of the arm, *C*, serves to support a blowpipe.

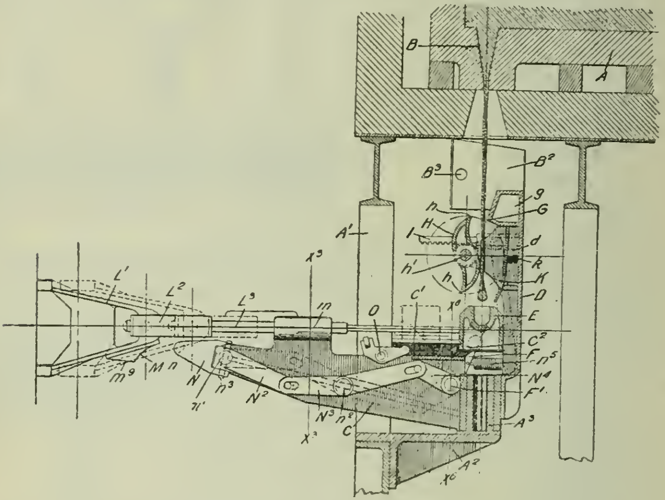


FIG. 232.

The blowing machine comprises a rotary head to which arms, L^1, are pivoted, and supports, L^2, pivoted to these arms carry blowpipes, L^3. As the machine rotates, it inserts a blowpipe, L^3, into the guide, *m*, and moves the pipe inwards towards the mould, *E*. The support, L^2, then engages a sliding rod mounted alongside the guide, *m*, and, by moving it inwards, causes rotation of the knife, *H*, and thus severs a charge of metal from the stream. Almost at the same time, the support, L^2, engages an arm, *N*, connected with the lever, *F*, and thus turns the mould, *E*, on to its side. The end of the pipe enters the moulding space and presses against the charge of metal therein, so that the parison is formed and stuck on to the end of the pipe. Further movement of the machine withdraws the pipe and its attached parison, and a spring, n^5, restores the mould to its upright position ready to receive more metal. To control the temperature of the stream of metal, it may be surrounded by a shield, B^3, having a pipe, B^3, through which a gas flame or an air blast may be introduced as desired.

A modified form of feeding device is shown in Fig. 233. In this form, the mould block, E^1, has four mould cavities instead of the single cavity shown in the previous construction, and the mould is turned through a right angle to present a parison to the blowpipe. The descending stream of metal is received on an inclined trough, which is carried by a standard, D^1, mounted on the pin, A^3. The trough is mounted at its front end on a horizontal pivot, r, and may be tilted about this pivot by a set screw, r^1, so that the inclination of the face of the trough may be altered. The metal flows down the trough, and by adjusting the screw, r^1, the cross-sectional area of the flowing stream can be varied at will according to the size of parison to be worked. The charge is cut off from the stream by a combined cutter and presser, H^1, which oscillates about its pivot, as shown in dotted lines, and co-operates with a fixed cutter, G, situated below the lip of the trough. The member, H^1, not only cuts off a charge of metal, but presses it into the mould. The trough, R, can be rotated about the pin, A^3, and can thus supply metal to a number of machines arranged in a circle about the pin. This modified form of feeding device

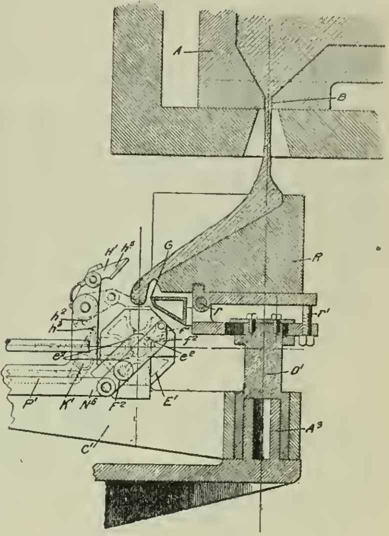


FIG. 233.

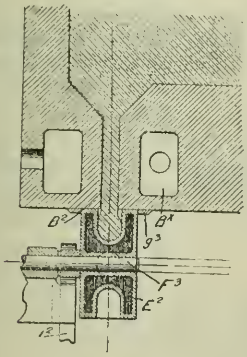


FIG. 234.

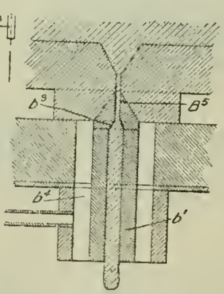


FIG. 235.

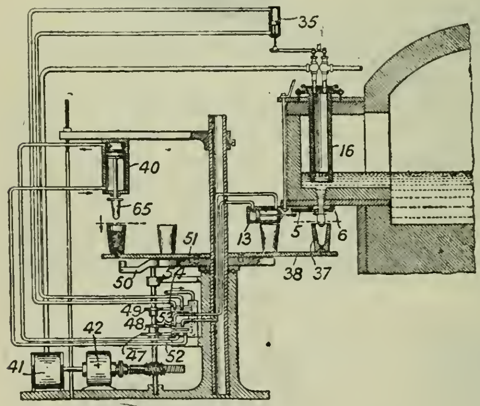
is the subject of a separate patent, No. **1256980**, and another modification is the subject of a third patent, No. **1323450**.*

A further modification of the invention, shown in Fig. 234, consists in forming an exit orifice in the side or bottom of the tank and having a rotating mould block, E^2, having one or more mould cavities fitting closely against a curved face plate, g^3, attached to the tank face around the outlet. Heating passages, B^x, surround the outlet.

As pointed out above in connection with the device shown in Fig. 233, it is advantageous to have the falling stream of metal of nearly the same cross-section as that of the mould cavity. This may be secured, as shown in Fig. 235, by connecting the exit orifice, B^5, of restricted size, with a discharge tube, b^1, of greater area, and in surrounding the discharge tube with a space, b^4, into which a cooling fluid may be introduced. The stream thus increases in area as it leaves the tube, B^5, to the desired cross-section, and, being chilled, descends in a solid stream of approximately the same cross-section as the parison. G. D.

364. Automatic Glass Feeding Device. R. E. McCauley, Stockton, California, U.S.A. (Brit. Pat. No. **135454**. January 6th, 1919, No. 360).—Relates to apparatus for delivering molten metal of the kind described in Specification 113665, combined with a machine for moulding glass articles under pressure. The table, 38, carrying the moulds, 37, is rotated intermittently by a Geneva-stop mechanism, 50, 51, from a motor, 52, which also operates a blower, 41. The cut-off knife, 5, pneumatic delivery device, 16, and the pressing plunger, 65, are controlled by the pneumatic cylinders, 13, 35, 40, the air supply to which is controlled by valves, 53, 54, 52, operated by cams, 48, 49, 47. Fig. 237 shows one of the valves 52, 53, 54. In the position shown, the compressed air flows

Fig. 236.



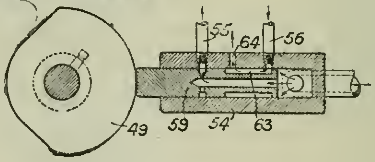


Fig. 237.

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* This Journal, Abs. 1919, **3**, p. 275.

as shown by the arrows. When the valve plunger, 59, moves to the left, the air passes directly into the pipe, 56, and the exhaust from the pipe, 55, passes through the port, 63, into the air by way of the hole, 64. The frame, 6, in which the shearing knife, 5, works is water-cooled. H. G. C.

365. Feeding Device for Glass-making Machinery. Hartford-Fairmont Co., New York, U.S.A. (Brit. Pat., November 12th, 1919, No. **141320**).—Relates to apparatus for feeding to moulding, etc., machines the charges delivered regularly from a tank, 2. The charges fall upon a curved distributor, 14, pivoted at 17 to a ring, 10, which is mounted in a bearing, 11, so that it can be turned automatically by cam mechanism to deliver the charges down a short trough, 15, successively to a number of troughs, 25 (Fig. 238), each leading to a glass-working machine. When it is desired to stop feeding all the machines without stopping the delivery from the tank, 2, the distributor, 14, is tilted downwards, as shown in Fig. 239, by a handle, 24, at the distributor, or an extension, 63, at the machine. This allows the charges to fall through the ring, 10, into the cullet pit. If a particular machine is to be put out of action, its trough, 25, is raised, as shown in Fig. 238, so that the charges leave the short trough, 15, and are deflected by a plate, 50, down a shoot, 65, into the cullet pit. The trough, 15, may be arranged to discharge directly to the machines, and in this case the machine tables, 6, may rotate continuously. The troughs, 25, etc., are sprayed with liquid from nozzles, 72. H. G. C.

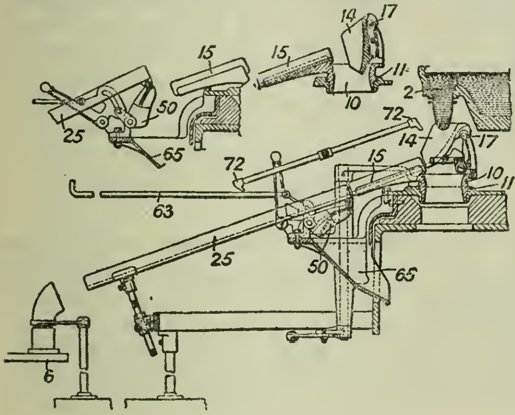


Fig. 238.

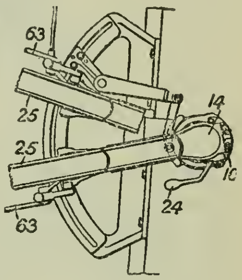


Fig. 239.

366. Glass Feeding Device. Empire Machine Co., New York, U.S.A. (Brit. Pat., February 9th, 1920, No. **138895**).—Relates to the delivery of uniform charges of molten glass from tank furnaces. The object of the invention is to prevent or to minimise the chilling or scarring of the charge by the shearing mechanism. Molten glass flows from the tank, 1, through a control valve, 22, and down a spout, 3, level with the end of which is a fixed water-cooled ledger blade, 6^a. The charges are severed by a water-cooled, four-armed rotating shearing device, 10, and drop through a hole, 20, on to a carrier, which conveys them to the forming mechanism. The shearing mechanism is enclosed in a chamber, 4, which is heated by burners, 5. By this means, the end of the glass stream flowing from the spout, 3, which has been chilled by the last shearing operation, is re-heated by the hot gases in the chamber. The fluidity of the glass stream, and hence its cross-section, can be regulated by the burners, 5.

H. G. C.

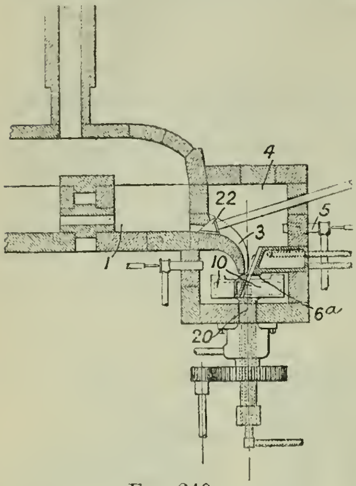


Fig. 240.

367. Machine for Fire-polishing Tumblers and other Glass Articles. H. H. Pitt (U.S.A. Pat., June 24th, 1919, No. **1307453**. Filed August 7th, 1917, No. 184954).—A machine for fire-polishing tumblers constructed according to this invention is characterised in that means are provided for passing water, steam, or air through the plugs which support the tumblers. The supporting plugs are arranged round the periphery of a horizontal

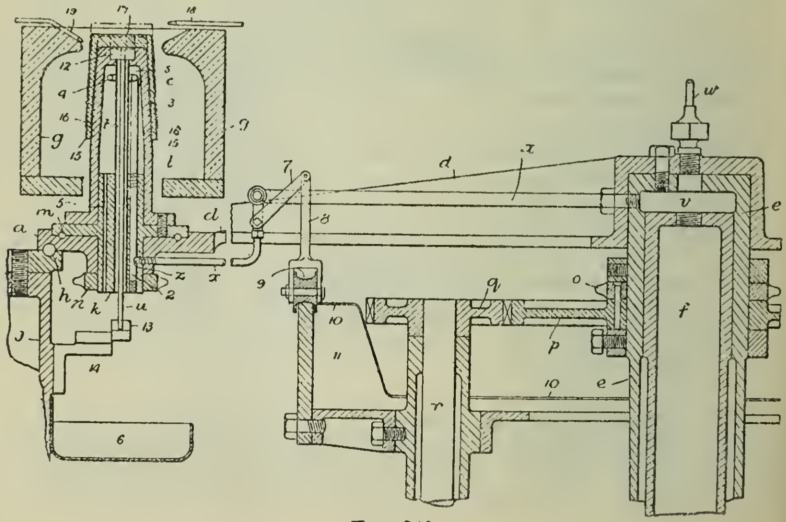


Fig. 241.

circular table, which, in rotating, carries the tumbler supports through a furnace or glory-hole, *g*. The plugs, *b*, are mounted on ball bearings, *m*, and are rotated by a chain passing round the outer side of the chain wheels, *n*, mounted on the plug shafts and round a central chain wheel, *O*. Each plug is hollow, and its cavity is filled with water supplied under pressure from the central chamber, *v*, in the hub of the machine. A port, *z*, in the shaft of the plug is adapted to register with the end of the pipe, *x*, once each revolution of the support, thus giving a regular supply of water to the interior of the plug. Excess water is led away through the hole, 5, from which it drips into a circular tray, 6. In order that water shall only be supplied to the plug as it is passing through the furnace, a cock is provided, and controlled by the lever, 7, which in turn is operated by the rod, 8, co-operating with the raised cam, 11, on the track, 10, opposite to the furnace. The central spindle, *u*, is raised and lowered alternately by a switchback circular track, 13, on which the lower end of the rod runs. This movement carries the tumbler upwards and allows the flame in the furnace to pass, to some extent, into the inside of the tumbler, thus smoothing the edge, 15, and at the same time preventing the tumbler from contracting on to the plug. S. E.

368. Grinding, Polishing, and Bevelling Glass. P. Ettinger and W. Forber, Liverpool (Brit. Pat. No. **136020**. February 1st, 1919, Nos. 2531 and 3518).—In glass grinding, polishing, or bevelling machines, the mixture of abrading material and fluid is automatically supplied to the bevelling wheel or to the polishing table by means of an oscillating trough, *Q*, which is caused by the reciprocation of a rod, *N*, to rock about a pivot bolt, *R*, so that it alternately dips into a cistern, *C*, containing the abrading mixture, and then deposits this on the wheel or table. The rod, *N*, is reciprocated by means of a crank pin on a disk, *L*, which is rotated through worm gearing, *I*, by a shaft, *D*; the shaft, *D*, also carries a stirrer, *F*, which keeps the abrading material well mixed. The oscillation of the trough may be started or stopped by means of a foot-operated clutch, *X*. The abrading material may comprise pumice, emery, carborundum, colcothar, rouge, rotten-stone, etc. H. G. C.

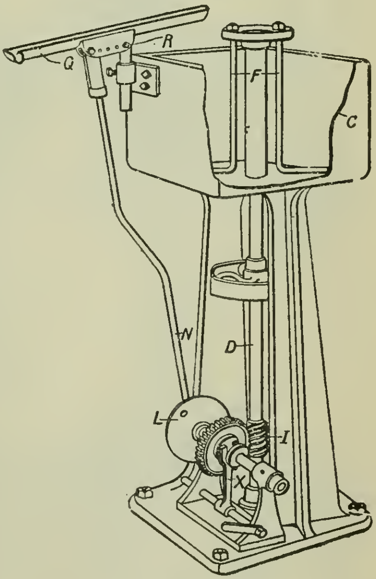


Fig. 242.

369. Bevelling Lenses, etc. H. J. Birchall, Erdington (Brit. Pat. No. **135354**. January 2nd, 1919, No. 30).—In a grinding machine for double bevelling the edges of eyeglass lenses, etc., in which two grinding-wheels are employed, one for each bevel, movable to and from the lens under the control of a pattern or former mounted on a rotating shaft which carries the lens, etc., the shaft is made in two parts, between the opposed ends of which the lens is mounted, and means are provided whereby the axial position of the former on the shaft can be adjusted relatively to the thickness of the lens, so that the apex of the V-bevelling is always in the centre of the thickness of the lens, etc. The divided shaft, j, has a part with an end, j^2, mounted for rotation only in a bearing, k, and driven by spur-gears, k^5, k^6, the other part, j^4, of the shaft, having an end, j^3, being driven at the same speed by exactly similar gearing, k^9, k^{10}.

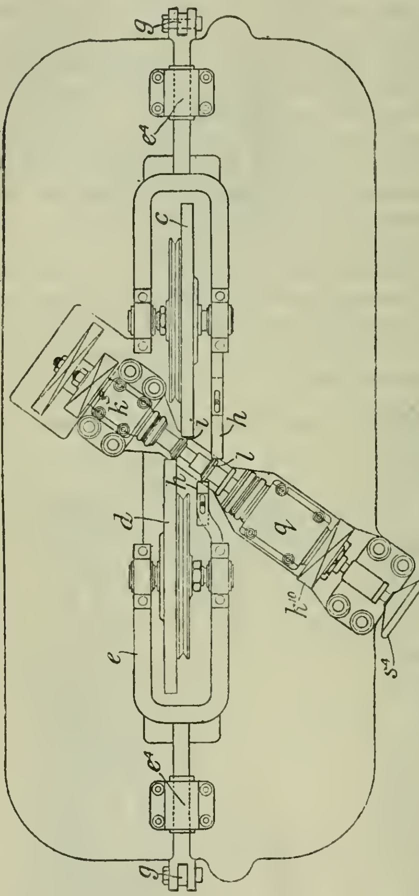


Fig. 243.

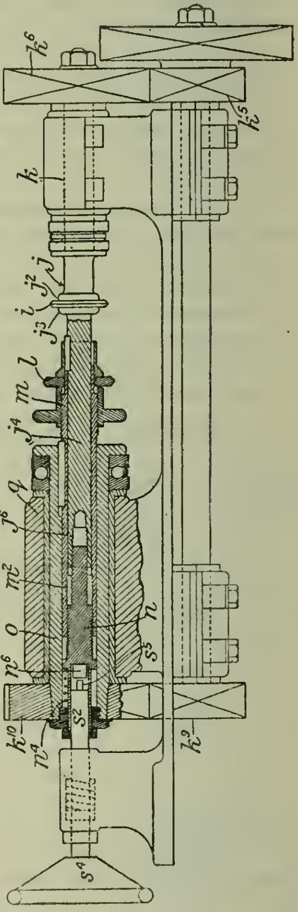


Fig. 244.

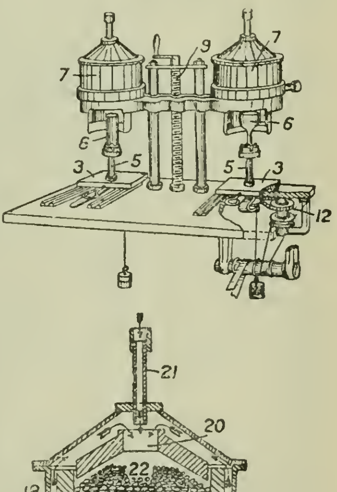
The lens, i, mounted between the ends, j^2, j^3, is ground by the peripheries of the grinding-wheels, *c*, *d*, which are movable to and from the lens by the engagement of a former, *l*, with followers, *h*, carried by the grinding-wheel frames, *e*, and held up to the former by weights adjustably mounted on levers, *g*. When a lens of different thickness is to be ground, the former is moved axially along the shaft by a distance equal to half that moved by the end, j^3, this movement being brought about by the following means. The sleeve, *m*, carrying the former is slidably keyed on the part j^4 of the divided shaft, and is also slidably keyed in a sleeve, *o*, rotatably mounted in a bearing, *q*, and driven by the gear, k^{10}. The ends of the sleeve, *m*. and the shaft, j^4, are internally screw-threaded at m^2 and j^6, respectively, the pitch of the thread m^2 being half the pitch of the thread j^6, and in engagement with these threads is a screwed plug, *n*, slidable in the sleeve, *o*, and pressed by a spring, n^4. The plug is adapted to be rotated by means of a hand-wheel, s^4, mounted on a spring-pressed shaft, s^2, which is moved axially to engage the part s^5 with the part n^6 of the plug; the holding pressure of the end j^3 on the lens is due to the spring, n^4. The grinding-wheel frames are guided by means of rollers running on guide-rails and by means of bearings, e^4. According to the Provisional Specification, the grinding wheels may be laterally adjustable.

H. G. C.

370. Remelting the Sharp Edges of Glass Articles. M. Mathy, 14, Place des Franchises, Liège, Belgium (Brit. Pat. No. **137660**. February 27th, 1919, No. 4956).—Relates to apparatus for re-melting the sharp edges of glass articles left by cutting. The glass article, 6 (Fig. 245), is placed on a spindle, 5, carried by a slide, 3, which is pushed forward to bring the article into a furnace, 7. In this position, a pulley on the lower end of the spindle, 5, engages a belt, 12, which causes the spindle, 5, to rotate. The screw, 9, adjusts the height of the furnaces, 7. Fig. 246 shows a section of the furnace, 7. Air entering a pipe, 17, is heated during its passage up the annular space, 18, to the aperture, 20, where it mixes with gas from a pipe, 21. Combustion takes place in the pores of a refractory mass, 22. The hot gases pass down through holes, 23, and melt the edges of the article, 6. No flame comes into contact with the glassware.

H. G. C.

Fig. 245.



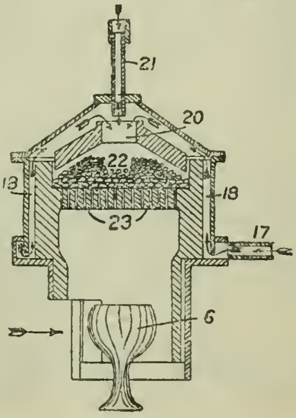


Fig. 246

371. Cracking-off and Remelting Machine. ALBERT B. KNIGHT (U.S.A. Pat., January 1st, 1918, No. **1251541.** Filed November 28th, 1918, No. 133939).—The invention consists of a machine for cracking-off and glazing the ends or necks of electric lamp bulbs (or of other glass articles with necks) so that they leave the glass-works ready for making up into lamps. The machine consists of a rotary table, 26 (Fig. 247), which carries a number of bulb-holding devices, 52. Each holder consists of a horizontal tubular spindle, 53, which has at one end a suction-cup, 62, and at the other end is connected through a valve, 71, and a distributing drum, 68′, with a vacuum pump driven by the rotating gear of the table. The valve is opened or closed by a stationary cam, 86, and while it is open a bulb, *A*, placed in the suction-cup, is held in a horizontal position, as shown. The spindle, 53, and therefore the bulb, is rotated by bevel wheels, 58, and a stationary gear, 25. The bulb is also supported by a pivoted arm, 87, which is lifted by a cam track, 92, after a bulb is placed in the holder.

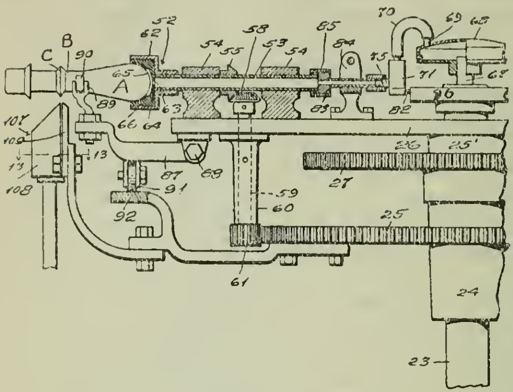


FIG. 247.

A bulb inserted in the machine is first carried beneath a scoring device consisting of a block of emery, 106 (Fig. 248), yieldingly held, which scores the edge of the bulge, *C*, in the neck of the bulb. The bulb then passes over burners, 107, the flames of which heat the scored neck until it cracks. The further movement of the table carries the bulb over other burners which heat the cracked-off end of the neck until the edge is glazed. G. D.

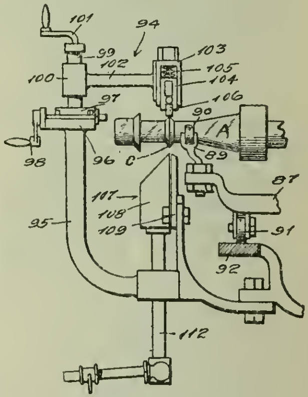
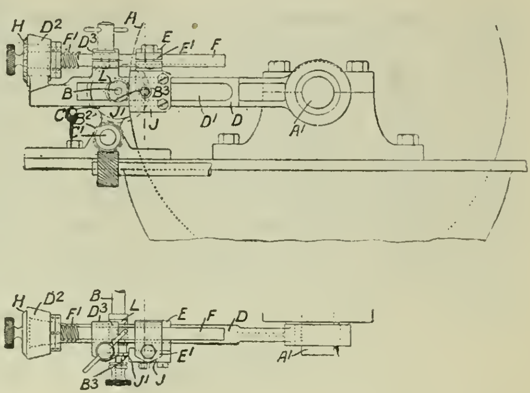


FIG. 248.

372. Grinding Lenses. H. E. RITTMEYER, London (Brit. Pat. No. **135401**. March 5th, 1919, No. 5468).—In a machine for grinding the edges of lenses, of the kind in which the lenses and a templet are mounted on a rocking support to rotate together about an axis parallel to the axis of the grinding-wheel, the templet bearing against an abutment, the abutment is carried upon a support mounted to rock about the axis of the grinding-wheel, and is so connected with the lens support that it is rocked with and by the rocking movement of this. The lenses and the templet are carried by a spindle, *B*, mounted in a support, *C*, adapted to rock about an axis, C^1, and the spindle is rotated through gearing, B^2, by the grinding-wheel shaft, A^1. An arm, *D*, slotted at D^1, is mounted to swing about the shaft, A^1, and has formed thereon a head, D^2, carrying an adjusting nut, *H*, and a clamp, D^3; the slot, D^1, is engaged by a slidable block, *L*, embracing the spindle, *B*, and by a roller carried by a saddle, *E*, on which is mounted the abutment, *J*, having a face, J^1, of the same radius as the grinding-wheel, *A*. The saddle, *E*, has formed thereon a clamp, E^1, adapted to slide on a spindle, *F*, which has at one end a screwed part, F^1, engaging the nut, *H*; the spindle, *F*, is also slidable in the clamp, D^3. The machine is set by means of two disks, B^3, mounted on the spindle, *B*, and by means of the clamps, E^1, D^3, and the adjusting nut, *H*; the rocking movement of the arm, *D*, causes the points of contact of the lenses with the grinding-wheel and of the templet with the abutment always to lie in the plane of the axes of the grinding-wheel and of curvature of the templet at its point of contact with the abutment. In a modification, Fig. 250, compensation for the wear of the grinding-wheel, *A*, is provided for by mounting on the saddle, *E*, an extension with a rack, *O*, on its underside engaging a pinion, O^1, loosely mounted to rotate on the axis of the shaft, A^1, and engaging a second rack, *P*, connected with a roller, *S*, mounted on a spindle,

Fig. 249.



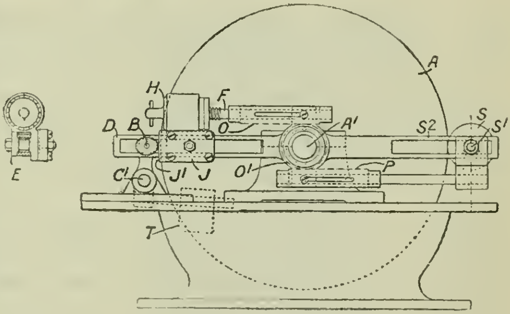


Fig. 250.

S^1, slidable in a guide, S^2, so that pressure of the templet on the abutment, due to a weight, T, holds the roller constantly against the surface of the grinding-wheel; as this wears, the abutment moves rapidly inward by an amount equal to the wear.

H. G. C.

373. The Construction of Mirror-polishing Machines in France. (*Diamant* 1918, **40**, 99, 114).—Two machines were described which worked on the same general principle. The mirror to be polished was cemented to a horizontal table which could be rotated about a vertical axis, and was also capable of a horizontal sliding motion. The polisher, a plate of equal size, consisted of many small polishers, also capable of rotation about a vertical axis, but eccentrically to the table carrying the mirror. The weight of the polisher could be counterbalanced to any desired extent by a lever arrangement. The two machines described differed in the manner of mounting the small polishing discs which made up the large polisher.

J. R. C.

Review.

The Ceramic Industries Pocket Book. By ALFRED B. SEARLE. (Sir Isaac Pitman and Sons, Ltd., 1920. 8*s*. 6*d*. net.) —This small volume contains a considerable amount of valuable and useful data brought together in a concise and handy form. The contents are compiled from various sources, and include numerous tables, some of which, taken from Continental journals, are not readily available to the majority of manufacturers in this country.

Though only four pages deal specifically with glass, a great amount of the information compiled will be found of considerable interest to the glass manufacturer, particularly in the refractory materials section of the industry. Numerous data given relating to plant and machinery are of general interest, and should be useful to those concerned with power production and transmission. Orthographical errors are rather frequent in the text, and more careful proof reading would have been advantageous. Thus on p. 15 appears: "it is necessary to use . . . clays . . . low in *air* compounds to produce goods of light colour." The melting point of lead is given as 3220° (p. 63). On p. 75 the approximate percentage composition of Jena laboratory glass is given as CaO 20, SiO_2 65, B_2O_3 15. On p. 228: "to convert a volume of slip in cubic inches into pints, multiply by 28·5; quarts, multiply by 57; litres, multiply by 16·15."

The inclusion of the English Ceramic Society and the Society of Glass Technology under the heading of "Employers' Associations" (p. 247) is, to say the least, very misleading.

In spite of numerous small errors, the book should prove very useful, particularly to those concerned with the clay industries.

J. H. D.

JOURNAL
OF THE
SOCIETY OF GLASS TECHNOLOGY

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